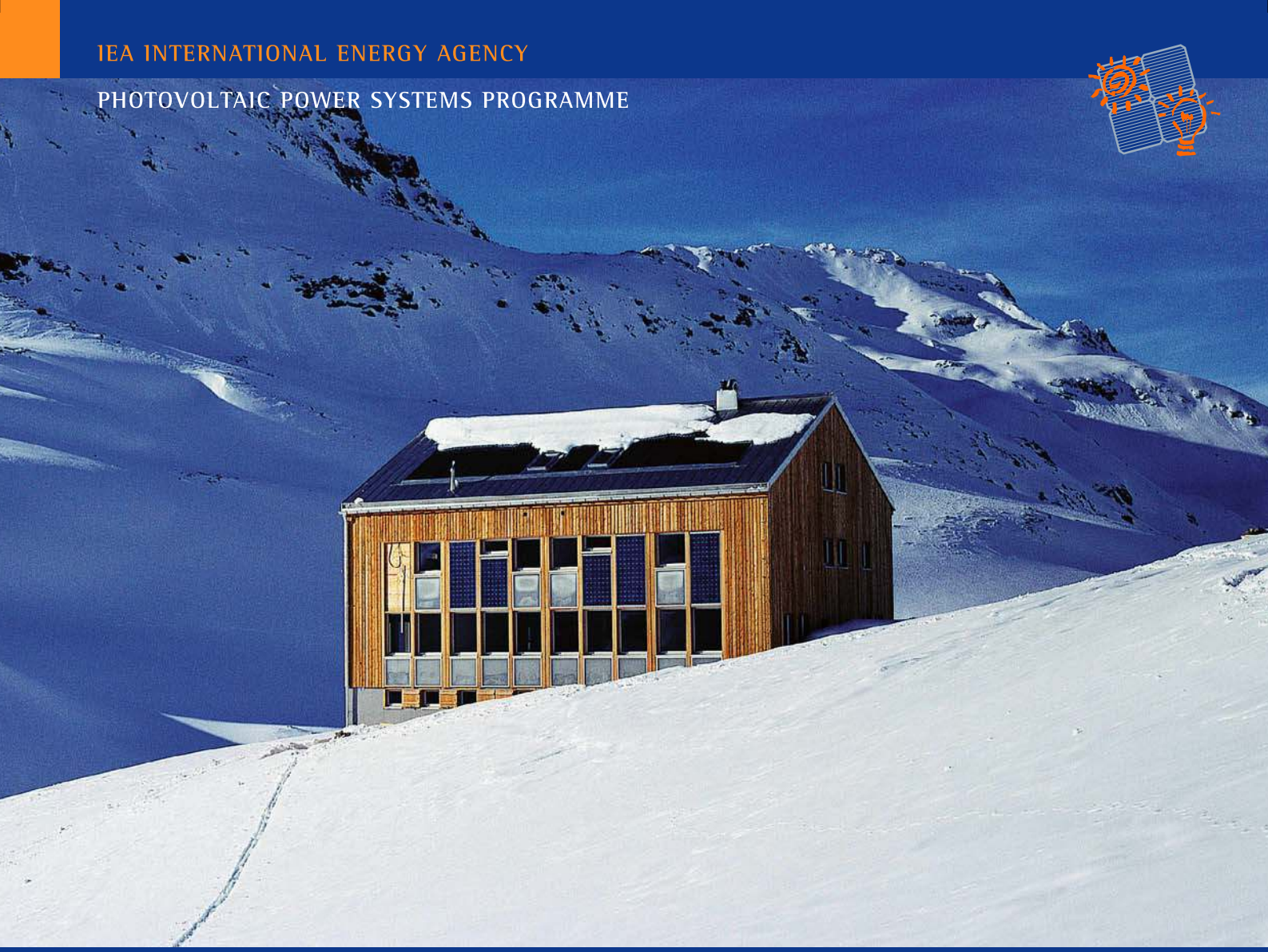
IEA INTERNATIONAL ENERGY AGENCY

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME



PVPS

annual report 2001

IMPLEMENTING AGREEMENT
ON PHOTOVOLTAIC POWER SYSTEMS

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

ANNUAL REPORT 2001

PREFACE

It is a pleasure for me to write this preface to the IEA PVPS annual report. Since spring of 2001, I have the honour to serve as the new PVPS chairman, following my highly estimated predecessor and friend, Erik Lysen, from the Netherlands. During the years I have worked with Erik, I have experienced his deep commitment to our common goals and his continuous effort for the sake of our cooperative agreement. On behalf of the Executive Committee and the Operating Agents, I would like to express my gratitude to Erik Lysen for leaving our Implementing Agreement in such a healthy and well-structured state. Together with Erik, the PVPS Executive Committee also had to say good-bye and thank you to the former Executive Secretary, Mrs. Hester Pruiksma. Her invaluable support for PVPS remained constant throughout the year and I would like to thank her for this flexible availability in the transition phase which made my first months much easier.

I was very happy to have found the support of Harry Schaap from Australia who was readily available to work with me as the new deputy chairman. With the new Executive Secretary, Mrs. Mary Brunisholz, we were finally successful in completing the new team chairing IEA PVPS. We are happy to have the strong and continuous support from the members of our Executive Committee as well as the Operating Agents and their expert groups.

As we all know, 2001 has been a difficult year with unexpected tragic events which have once again revealed the vulnerability of our society. As for many others, our common work also suffered from the consequences of these events as national security reasons had implications on foreign travel for a number of our members. However, I am convinced that our work is even more important as it seeks to provide contributions to solutions for a sustainable energy supply, to energy security and to electrical energy provided to those who lack this fundamental need.

By the end of 2001, two very productive projects came to their formal closing: Task 5 on the design and grid interconnection of building integrated and other dispersed photovoltaic systems and Task 7 on photovoltaic power systems in the built environment. Both projects have resulted in a wealth of new information and experience which can make important contributions to the deployment of grid-connected photovoltaic systems. The results of these, as well as the ongoing Tasks are described in the following pages. As in previous years, the development of photovoltaics in our member countries is described in the country sections, providing the latest information on the national framework, specific initiatives and particular experiences. This country-specific information is now also available from the PVPS-website (www.iea-pvps.org).

Increasingly, PVPS is called to interact with other implementing agreements and energy technologies. This is a clear sign of a market oriented transition where energy solutions prevail the technology. The most recent work within PVPS is concerned with follow-up activities in the field of building integrated applications where a new project, Task 10, is presently being discussed. In the sequence of the Photovoltaic Executive Conferences, a further issue of these conferences is presently being planned for spring 2003, to be hosted by Japan.

Stefan Nowak
Chairman

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PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

IEA

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD), which carries out a comprehensive programme of energy co-operation among its member countries. The European Union also participates in the work of the IEA.

Collaboration in research, development and demonstration of new technologies has been an important part of the Agency's Programme. The IEA R&D activities are headed by the Committee on Research and Technology (CERT), supported by a small secretariat staff, with headquarters in Paris. In addition four Working Parties on End Use, Renewable Energy, Fossil Fuels and Fusion, are charged with monitoring the various collaborative energy agreements, identifying new areas for co-operation and advising the CERT on policy matters. The Renewable Energy Working Party (REWP), recently chaired by the first PVPS chairman, Mr. Roberto Vigotti, oversees the work of eight renewable energy agreements, of which PVPS is one of the youngest, and is supported by a Renewable Energy Unit at the IEA secretariat in Paris.

IEA-PVPS

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the collaborative R&D Agreements established within the IEA, and since its establishment in 1993 the PVPS participants have been conducting a variety of joint projects in the application of photovoltaic conversion of solar energy into electricity.

The overall programme is headed by an Executive Committee composed of representatives from each participating country, while the management of individual research projects (Tasks) is the responsibility of Operating Agents. By the end of 2001 nine Tasks were established within the PVPS programme, of which one was completed in 1997 (Task 6) and one is not operational (Task 4).

The twenty-one PVPS members are: Australia, Austria, Canada, Denmark, European Union, Finland, France, Germany, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom and the United States. Turkey has shown an interest to revive its membership.

The mission of the IEA-PVPS programme is:
To enhance the international collaboration efforts through which photovoltaic solar energy becomes a significant renewable energy source in the near future.

The underlying assumption is that the market for PV systems is gradually expanding from the present niche markets of remote applications and consumer products, to the rapidly growing markets for building-integrated and other diffused and centralised PV generation systems.

The primary scope of the programme has been the information exchange about activities already in progress in the respective national programmes. But the real added value of the co-operation has been the informal co-ordination and initiation of new activities such as market surveys, the analysis of the operation and performance of a large number of PV systems already installed in the world, and the provision of the lessons learned as well as the guidelines for appropriate design improvements.

IEA-PVPS OBJECTIVES

The IEA-PVPS programme aims to realise the above mission by adopting the following objectives related to reliable PV power system applications for the target groups: utilities, energy service providers and other public and private users:

1. To contribute to the cost reduction of PV applications

National RD&D programmes, utility investments in PV projects, industrial R&D and expansion of PV manufacturing capacity are examples of activities with a direct effect on the cost of PV systems and their application. International co-operation can indirectly contribute to cost reduction by undertaking or supporting activities such as: sharing objective information, creating networks and providing guidelines.

2. To increase the awareness of their potential and value

Key issues for the awareness of the potential and value of PV power systems among target groups are: cost/performance indicators, market developments, innovations and breakthroughs, new applications and services, national and international programmes and initiatives, financing schemes, developments and standards.

3. To foster their market deployment by removing technical and non-technical barriers

Critical technical and non-technical barriers for the large-scale deployment of PV power systems in various market segments have been identified, as described in Chapter 1. International co-operation adds value in the assessment of some of these barriers, such as: standardisation in design, utility disinterest and concerns, networks of installers, technical risks etc.

4. To enhance technology co-operation with non-IEA countries

Stand-alone systems in remote areas of the world represent a fast growing market segment and their large-scale introduction is supported by bilateral and multilateral agencies and development banks. The large-scale introduction is hampered by various barriers such as acceptable accessible financing structures, institutional and social problems, infrastructure issues and sometimes technical problems. PVPS expertise can be instrumental to help overcome some of these barriers.

TABLE 1 - STRATEGIES AND DELIVERABLES OF THE FOUR IEA-PVPS OBJECTIVES

OBJECTIVE	STRATEGIES	DELIVERABLES
1 – To contribute to the cost reduction of the PV power systems applications	• To collect, analyze and disseminate information on the technical performance and cost structure of PV systems and their applications. • To share the knowledge and experience gained in monitoring selected national and international PV projects. • To provide guidelines for improvement of the design, construction and operation of photovoltaic power systems and subsystems. • To contribute to the development of improved photovoltaic systems and subsystems.	• Reliable information on the technical performance and cost structure of PV systems, in an accessible form. • Recommended practices for improved design, construction and operation and maintenance of PV systems, in an accessible form. • Technical guidelines fot the interconnection to the grid of small dispersed systems as well as large and very large PV systems. • Recommended practices for the main components of PV sys-tems.
2 – To increase the awareness of the potential and value of PV power systems	• To collect and analyze information on key aware ness issues, such as markets, applications, barriers and success stories; • To present/publish the reliable and relevant parts of this information in appropriate forms (brochures, reports, books, internet etc.); • To disseminate these information products, relevant for the deployment of PV systems, to target groups; • To monitor the use of this information and the effects on the awareness among target groups; • To bring actors of different groups together, and to encourage the creation of national and interna-tional networks.	• The PVPS Newsletter informing the main target groups on the results of the collaborative work of the PVPS programme and on other important issues regarding the deployment of PV power systems.programme. • An overview of activities, available information and contact points of the PVPS programme on the Internet. • A Flyer describing the objectives and the structure of the programme and containing a list of the contact persons in each country. • Executive Conferences • International workshops on important specific (technical and non-technical) issues • Input to national workshops by participation of PVPS experts.
3 – To foster their market deployment by removing technical and non-technical barriers	• To involve and support utilities and other public and private users in the process of identification, selection and implementation of high priority activities aimed at removing the barriers concerned. • To develop methods for the evaluation of the value and benefits of PV systems and to facilitate their introduction. • To develop strategies for the deployment of PV in a competitive electricity market and to facilitate their introduction. • To assess the evolution of the identified barriers for PV power-systems in the light of economics and competition in the electricity sector.	• Recommended practices for grid-connected and stand-alone systems, especially for utilities regarding the implementation of these applications. • Guidelines for monitoring practice and analysis of PV systems, to optimize equipment choices and improve the quality of monitoring. • Overview of PV financing methods in OECD countries. • Survey of taxation, customs duties and building regula-tions for PV components and systems in OECD countries. • Planning methods to evaluate and maximize the benefits of grid-connected photovoltaic systems to the electric grid and to the customers. • Specific studies on important issues.
4 – To enhance technology co-operation with non-IEA countries	• To stimulate the awareness and interest of multilateral and bilateral agencies and development banks on the technical and economic potential and best practice of PV systems. • To stimulate co-operation between IEA PVPS members and selected non-IEA countries. • To increase awareness on the opportunities of PV systems amongst targeted groups in developing countries via works-hops, missions and publications. • To stimulate PVPS membership of selected non-IEA countries. • To promote adequate measures for quality assurance and standards.	• Internal staff workshops for multilateral agencies and development banks. • Workshops in non-IEA countries, co-ordinated with bilateral and/or multilateral agencies, development banks and/or NGO's. • Studies and publications on PV systems applications in developing countries. • Contact point for ad-hoc advice to staff of multilateral agencies and development banks. • Best practice deployment and implementation guide for successful PV system operation. • Active PVPS membership and/or participation of selected non-IEA countries.

In Table 1 the strategies and deliverables for each of these objectives are given.

IEA-PVPS TASKS

In order to obtain these objectives, specific research projects, so-called Tasks, are being executed. The management of these Tasks is the responsibility of the Operating Agents. Within the IEA PVPS the following Tasks have been established:

- Task 1. Exchange and dissemination of information on PV power systems
- Task 2. Operational performance, maintenance and sizing of PV power systems and subsystems
- Task 3. Use of PV power systems in stand-alone and island applications
- Task 4. Modelling of distributed PV power generation for grid support (not operational).
- Task 5. Grid interconnection of building integrated and other dispersed PV systems
- Task 6. Design and operation of modular PV plants for large scale power generation (concluded in 1997)
- Task 7. PV power systems in the built environment
- Task 8. Very large scale PV power generation systems
- Task 9. Deployment of PV technologies: co-operation with developing countries

The **Operating Agent** is the manager of his or her Task, and responsible for implementing, operating and managing the collaborative project. As such the Operating Agent compiles a status report, with results achieved in the last six months, as well as a work plan for the coming period. These are being discussed at the Executive Committee meeting, where all participating countries have a seat. Based on the work plan the Executive Committee decides whether activities in the coming period should continue, or intensified, or stopped. In case the Executive Committee decides to continue the activities within the Task, the participating countries in this Task commit their respective countries to an active involvement by national experts. In this way a close co-operation can be achieved, whereas duplication of work is avoided.

TASK STATUS REPORTS

TASK 1 – EXCHANGE AND DISSEMINATION OF INFORMATION ON PHOTOVOLTAIC POWER SYSTEMS

OVERALL OBJECTIVE

The objective of Task 1 is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives that relate to contributing to cost reduction of PV power applications, increasing awareness of the potential and value of PV power systems, fostering the removal of both technical and non-technical barriers and enhancing technology co-operation.

All countries participating in the PVPS Programme are members of Task 1. To meet the Task 1 objective and deliver the expected outcomes, Task 1 participants focus on understanding the needs of their target audiences for the various Task 1 deliverables and establishing mechanisms for communication both within and outside the PVPS Programme. The development of the public website www.iea-pvps.org will continue to be influenced by the requirements for information that are identified and revised by Task 1 participants and others.

Task 1 activities are organized into the following subtasks:

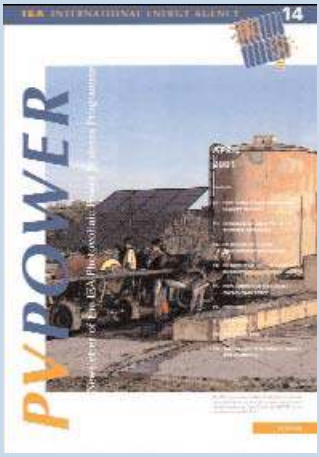
SUBTASK 1.1: Status Survey Reports

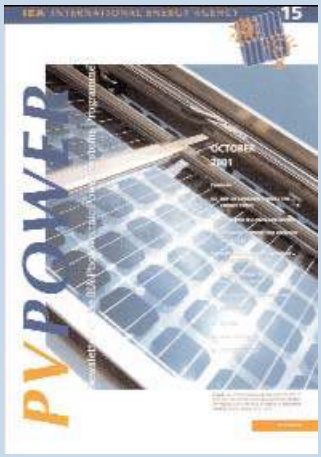
A published International Survey Report is compiled from the National Survey Reports produced annually by all countries participating in the IEA-PVPS Programme. Parts of these previously internal national reports can now be found on the public website. The International Survey Report presents the current status and interprets trends relating to systems and components being used in the various PV power systems markets, as well as changing applications within those markets. This is reported in the context of the business environment, policies and relevant non-technical factors in the participating countries.

International Survey Reports were initially produced every two years, but a shorter report is now produced annually to provide more timely information. The first issue was printed in March 1995 and a further five issues had been published by the end of 2001.

SUBTASK 1.2: Newsletter

A newsletter, PVPower, is prepared and distributed each six months presenting highlights of the IEA-PVPS Programme as well as general features of interest about PV systems and components and market applications. Task 1 participants provide material of interest to the newsletter editor and ensure that the newsletter reaches its target audience in the respective countries.
Fifteen issues of the newsletter had been published by the end of 2001.





Newsletter PV Power issues 14 and 15

SUBTASK 1.3: Special Information Activities

A variety of activities, including workshops and documents, provide analysis and summary assessment of special topics. These are directed at technical, economic, environmental and social aspects of PV systems and applications and are usually managed by a specific country or a group of countries from the Task 1 membership. Activities to date include workshops and published reports on "Environmental aspects of PV power systems," "Photovoltaics in competitive electricity markets" and "Added values of photovoltaic power systems." Other activities include "Buy back rates for grid-connected photovoltaic power systems," "Photovoltaic components and systems: Status of R&D in IEA countries, 1985-1995" and "Photovoltaics in cold climates." A new activity, "Estimating cost of energy from photovoltaic power systems," has commenced.

SUMMARY OF TASK 1 ACCOMPLISHMENTS FOR 2001

For all activities Task 1 emphasizes the importance of meeting the needs of the various target audiences and this focus has continued in general throughout the year. The public PVPS website enables PVPS information to be provided quickly and at a reasonable cost. Consequently, the ongoing development of the website remains a priority activity for Task 1. The website (and its various links) also provides other PVPS participants with valuable information on the programme as a whole, enhancing inter-task communication.

SUBTASK 1.1: Status Survey Reports

The sixth issue of the International Survey Report was published in September 2001 and analyzed data collected between 1992 and the end of 2000. The report was prepared under the supervision of Task 1 by an independent consultant on the basis of the National Survey Reports (NSRs) prepared by Task 1 participants. Eighteen out of twenty countries produced the required NSR (or at least provided information). Fifteen of these countries provided material close to the agreed date.

Some new information was requested in this NSR in response to outside interests – trends in system and module prices, and employment data, both from countries able to provide such information.

The International Survey Report was funded by the PVPS Common Fund and was distributed by Task 1 participants to their identified national target audiences and at selected conferences and meetings. The report is also available on the public website.

SUBTASK 1.2: Newsletter

Editorial policy for the newsletter continued to emphasize that projects and products must be tangible to be included.

Issue 14 of the newsletter was published in April 2001. Issue 15 was published in October 2001. Issues of PVPower are now available on the public website.

SUBTASK 1.3: Special Information Activities

Added values of photovoltaic power systems - Printed copies of the public report were sent to all countries in April 2001, and the report is also able to be downloaded from the public website. The report has formed the basis of presentations at a number of workshops in different countries.

Answers to frequently asked questions about solar photovoltaic electricity: an international perspective

- A set of questions and answers was developed within Task 1 and loaded on to the public website for use as a public resource.

Estimating cost of energy from photovoltaic power systems

- Work is underway. In particular, Task 1 has developed evaluation criteria to help assess various costing methodologies identified by Task 1 and others.

SUMMARY OF TASK 1 ACTIVITIES PLANNED FOR 2002

The issue of market implementation has been identified as an important focus for the PVPS Programme, and Task 1 will ensure that this theme is addressed in all activities. Further, Task 1 will informally begin to look at innovative marketing and financing strategies, which may then lead to development of a special information activity or provide input to a new task.

SUBTASK 1.1: Status Survey Reports

The target date for publication of the seventh issue of the International Survey Report is August 2002. Changes to the format and content of the seventh issue and an agreed timetable for production will be finalized during the March 2002 Task 1 meeting. National Survey Reports will be completed by the end of May 2002 so that the information can be incorporated in the International Survey Report.

SUBTASK 1.2: Newsletter

Task 1 participants will continue to review and update the target audience within their country, and to seek feedback regarding preferred format (e.g. electronic or printed) and content from these audiences.
PVPower Nos. 16 & 17 will be published in April 2002 and October 2002 respectively, maintaining current editorial policy.

SUBTASK 1.3: Special Information Activities

Estimating cost of energy from photovoltaic power systems – It is planned that during 2002 work will be substantially completed on the broad issues relating to estimating cost of energy from PV, the description of the costing elements relevant to both grid-connected and off-grid PV, and the review and assessment of methods commonly used in participating countries to calculate the cost of energy from PV systems.

INDUSTRY INVOLVEMENT

Task 1 activities continue to rely on close co-operation with PV industries, electricity utilities and other parties, both for collection and analysis of quality information and for dissemination of PVPS information to target audiences. This is achieved through the networks developed in each country by the Task 1 participants. Workshops are considered an effective means of attracting industry involvement in the PVPS programme, and are developed whenever possible.

KEY DELIVERABLES (2001 AND PLANNED)

The following were published and also made available on the public website during 2001:

Added values of photovoltaic power systems
Report IEA-PVPS T1-09: 2001;

Trends in photovoltaic applications in selected IEA countries between 1992 and 2000 Report IEA-PVPS T1-10: 2001;

Newsletter – PVPower issues 14 and 15;

An internal report on frequently asked questions and answers was circulated, and the material was also added to the website. National Survey Reports and guidelines are produced and updated each year.

During 2002 it is planned to produce the seventh issue of the International Survey Report, PVPower issues 16 and 17, internal and public reports on the costing activity and to disseminate information collected on innovative marketing and financing strategies. It is also planned to circulate NSRs to Task 1 members and to make some information from these reports available through the public website.

LIST OF PARTICIPATING COUNTRIES, KEY TASK 1 PARTICIPANTS IN 2001 AND THEIR ORGANISATIONS

In many cases the following participants were supported by one or more experts from their respective countries.

COUNTRY	NAME	ORGANISATION
Australia	Greg Watt	Australian PVPS Consortium
Austria	no participation	
Canada	Raye Thomas	representing CanSIA
Denmark	Peter Ahm	PA Energy A/S
European Union	Paul Doyle	DG 12
Finland	Leena Grandell	MOTIVA
France	André Claverie	ADEME
Germany	Peter Sprau	WIP
Israel	Yona Siderer	The Ben-Gurion National Solar Energy Centre
Italy	Salvatore Guastella	CESI - ENEL
Japan	Osamu Ikki	Resources Total System Co. Ltd.
Korea	Kyung-Hoon Yoon	KIER
Mexico	Jaime Agredano Diaz	IIE
Netherlands	Michiel van Schalkwijk	NOVEM
Norway	Bruno Ceccaroli	SCATEC AS
Portugal	Pedro Paes	Ministry of the Economy
Spain	no participation	
Sweden	Lars Stolt	Uppsala University
Switzerland	Pius Hüsser	Nova Energie GmbH
United Kingdom	Paul Cowley	IT Power
USA	Charles Linderman	Edison Electric Institute.

Up-dated contact details for Task 1 participants can be found on the IEA-PVPS website www.iea-pvps.org.

MEETING SCHEDULE (2001 AND PLANNED 2002)

The 18th Task 1 Participants' meeting was held in Aarhus, Denmark, 21-23 March 2001.
The 19th Task 1 Participants' meeting was held in Long Beach, USA, 7-10 October 2001.
The 20th Task 1 Participants' meeting will be held in Bodø, Norway, 13-15 March 2002.
The 21st Task 1 Participants' meeting will be held in Switzerland, 11-13 September 2002.

TASK 2 - OPERATIONAL PERFORMANCE, MAINTENANCE AND SIZING OF PHOTOVOLTAIC POWER SYSTEMS AND SUBSYSTEMS

OVERALL OBJECTIVE

The overall objective of Task 2 is to provide technical information on operational performance, long-term reliability and sizing of PV systems to target groups. The target groups of Task 2 are other Tasks of PVPS and PV experts, research laboratories, utilities and manufacturers, system designers, installers, standardisation organisations and vocational schools. Task 2 is a technical Task with a horizontal role to deliver services to the other Tasks within the PVPS programme. Maintenance of PV systems and subsystems is an important aspect of long-term plant operation and will be included in the Task activities.

Task 2 officially started its work on April 16, 1999, for a period of five years (second phase). Task 2 activities are organised into the following Subtasks:

SUBTASK 1: International Database

Participants collect information on the technical performance, reliability and costs of PV power systems and subsystems by means of published and unpublished written materials, available monitoring data from national programmes and personal contacts. The information is then entered into a database providing technical data on operational performance, long-term reliability and sizing of PV systems. To ensure consistency, a data collection format and a set of standard definitions have been developed and agreed to.

The Task 2 Performance Database allows the user to select PV system data, monitoring data and calculated results as well as to export these data into spreadsheet programmes. The Task 2 database is being updated regularly including new PV system data from national representatives and other sources. The product is distributed in a non-commercial way as widely as possible. Dissemination of the database and collated information is carried out through national channels of the participating countries, by organising national and international workshops, by presenting the products at conferences and seminars and last, but not least, by using the effective means of Internet.

SUBTASK 2: Evaluation of PV Systems

Participants analyse performance and maintenance data for photovoltaic power systems and components in their respective countries, both in order to ensure the quality and comparability of data entered in the database and to develop analytical reports on key issues such as operational performance, reliability, expected output and sizing of PV systems. Activities to date include conference presentations and published reports on a Statistical and Analytical Evaluation of PV Operational Data, analysis of the Operational Performance of the IEA Database PV Systems and analysis of Photovoltaic Systems.

SUBTASK 3: Measuring and Monitoring

Participants assess which current procedures for measuring the performance of photovoltaic power systems and subsystems are most effective, which can be improved, and which are best avoided. Activities included a published handbook covering monitoring techniques, normalised evaluation of PV systems and national procedures in IEA member countries. The internal PVPS Task 2 report, a Measuring and Monitoring Approaches," was published in November 1998 and has been distributed to other PVPS Task participants, a PV researcher and to individuals who have made a special request.

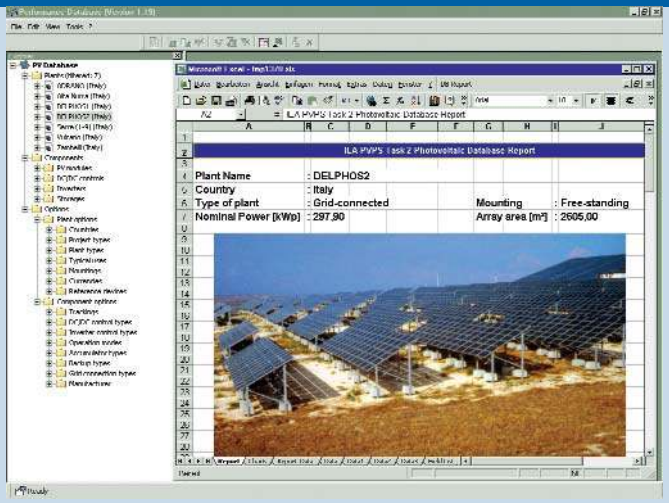


Fig. 1 - PVPS Task 2 Performance Database programme showing filter and data export tools for selected PV system

Subtask 3 was terminated during the first phase of Task 2. Activities on monitoring and maintenance are continued with less emphasis within Subtask 2.

SUBTASK 4: Improving PV System Performance

Participants are developing recommendations on sizing of PV power systems and suggest improvements for better PV system performance. Participants identify tools to process and analyse data for performance prediction and sizing purposes. Applied energy management schemes are analysed from the energy and operating cost points of view. Participants take account of the work performed in other Subtasks and in collaboration with Task 3 and Task 7.

SUMMARY OF TASK 2 ACCOMPLISHMENTS FOR 2001

During 2001, Task 2 focused on the dissemination of the Performance Database and other Task 2 products. The public Task website established in July 2001, enables downloads and technical information to be provided quickly and cost-effective to the users. The volume of visitors to the Task website, their countries and sectors as well as the number of PVPS Task 2 products retrieved are being tracked to measure the extent to which the website is visited and the products are used.

The organisation and execution of the first international **Task 2 workshop** became a priority activity for Task 2 since the beginning of the year. Condensed information on operational performance, reliability and promotion of PV systems has been presented and delivered to the target audience. The IEA-PVPS Task 2 workshop was held in Munich, Germany, on 24 October 2001, in conjunction with the European PV Solar Energy Conference and Exhibition and attracted a broad range of participants from many different countries and sectors.

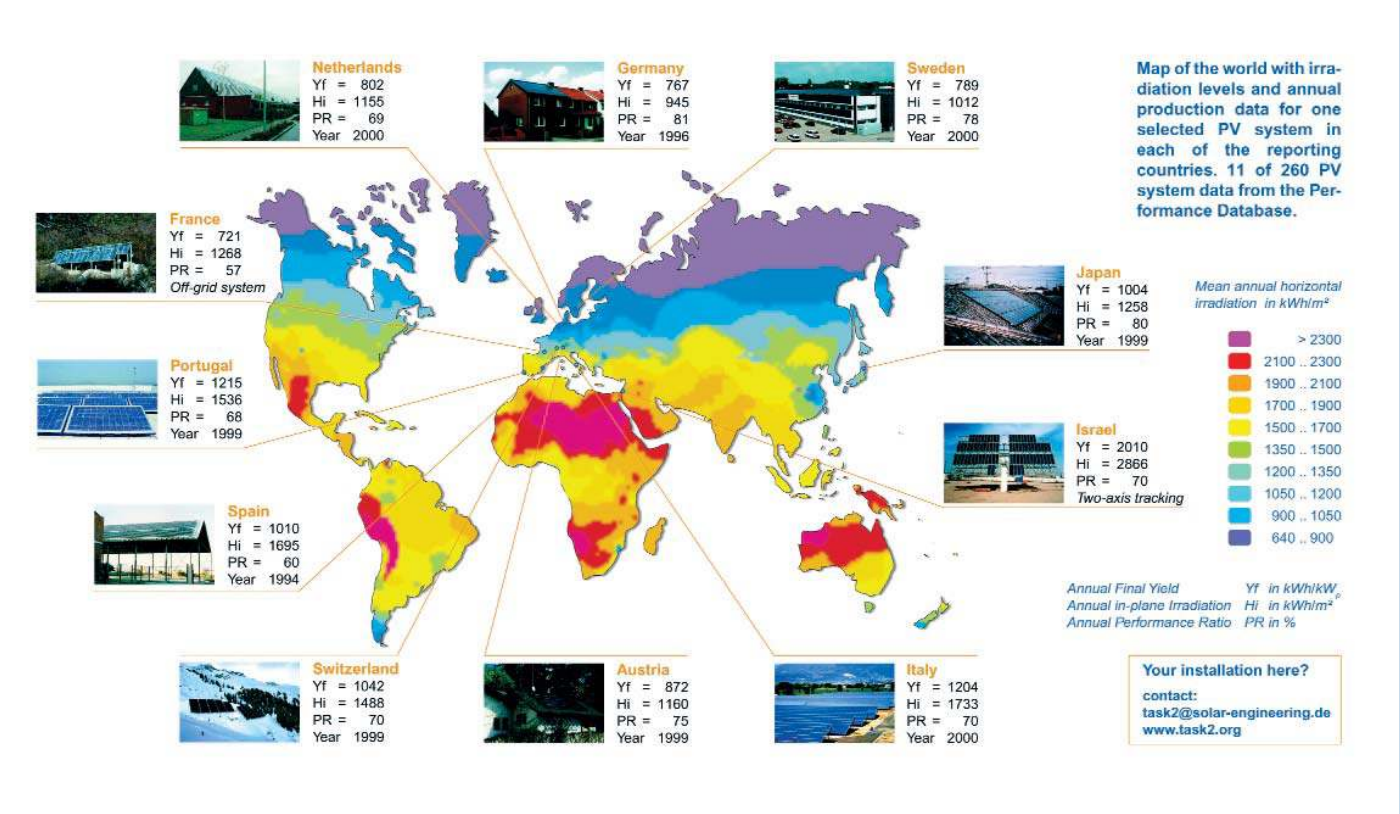


Fig. 2 - Map of the world with irradiation levels and annual production data for one selected PV system in each of the reporting countries: Eleven of 290 PV systems from the Task 2 Performance Database.

Organizing a joint Task meeting between **Task 2 and Task 7** in Yokohama, Japan, in September 2001, has enhanced inter-task communication. The exchange of information on architectural PV design criteria, trends in building integration, irradiation losses in the built environment and operational experiences and performance results has been fruitful to both Tasks.

SUBTASK 1: International Database

The **Task 2 Performance Database**, version 1.19, was published as a tool for planning, sizing and improving PV systems with respect to operational performance and reliability (see Figure 1). The database programme was upgraded and new datasets were entered which resulted in high quality data of 290 PV systems of different system technologies, located in eleven IEA countries (see Figure 2).

The Performance Database (45 MB) is available on CD-ROM and can be downloaded from the Task website "http://www.task2.org." An instruction manual, installation guide, database flyer and electronic user support are additionally provided to the database users. Since its first release in July 2001, 250 registered users from a broad range of sectors and 37 different countries have downloaded the Task 2 Performance Database during the second half of 2001 (see Figure 3). During the same period, a further 110 database programmes on CD-ROM have been distributed to vocational schools, to research laboratories, electricity utilities, industries (SME) and to the press on individual requests. For the promotion of the Performance Database, announcements were made on public PVPS and Task websites, as well as written articles in national and international PV magazines and newsletters. The database programme has been presented at PV conferences and in workshops.

Data collection was continued and focused on additional data sets from already existing PV systems, new types of PV systems (i.e. building integrated PV, facades and AC-modules) and PV systems in new countries. Due to various national programmes (e. g. Japan, Italy, Germany) and corresponding monitoring activities, representative data were collected by each Task participant and 30 new PV system data were imported into the PVPS Task 2 Performance Database during the year 2001. For easy data import into the Task 2 database, an Excel workbook is available, which includes automatic calculations of annual results and thus can be used for data checking and correction.

At present, 10 400 monthly data sets from 290 operating PV plants with an installed capacity of 8 MWp are provided in the Task 2 Performance Database. High quality PV system data are available from the following countries (see Figure 2): Austria, France, Germany, Israel, Italy, Japan, Netherlands, Portugal, Spain, Sweden and Switzerland. Data from PV installations in additional countries are most desired and available data will be included in the next database update.

SUBTASK 2: Evaluation of PV Systems

The activity of PV system performance analysis has been continued. All system and subsystem performance data have been evaluated in terms of operational performance and reliability. To a great extent, the evaluation procedures are based on the European Guidelines, Document B, taking small modifications into account. Additional parameters are introduced for the evaluation of stand-alone systems. Performance results are presented in standard format using normalised indicators such as energy yields (normalised to the nominal power of the PV array), efficiencies (normalised to the PV array area) and performance ratio (normalised to the in-plane irradiation).
A report on the Operational Performance, Reliability and Sizing of Photovoltaic Systems, has been prepared in conjunction with the Task 2 workshop held in Munich, Germany, on 24 October 2001, and will be published in the beginning of 2002.

SUBTASK 4: Improving PV System Performance

Different documents on simulation tools have been collected and evaluated. The overview on simulation tools will be continued and improved. Regarding energy management strategies (EMS), a draft version of a review on Energy Management Strategies for Hybrid Energy Systems, has been prepared in collaboration with Task 3. It will be made available to Task 2 and Task 3 experts early in 2002. Case studies have been selected to initiate activities on "optimum operational conditions for stand-alone hybrid systems."

SUMMARY OF TASK 2 ACTIVITIES PLANNED FOR 2002

Task 2 activities for 2001 will focus on the effective **dissemination of technical PVPS information**, which has been elaborated in all of the four Subtasks. The Internet option will be the preferred way of distribution. For the national distribution of the Performance Database, Task 2 will locate and activate distribution channels and contacts in their members' countries. Offering workshops relevant for target groups will be enhanced, as these activities seem to be attractive and of importance for the PV industry.

As PVPS and Task websites are the main distribution channels for Task 2 deliverables, further efforts will be invested to improve and update these sites. The **Task 2 website** will be further developed to become the choice of information dissemination and retrieval offering general PVPS information, a list of national contact persons, free downloads of Task 2 publications, free download of updated Performance Database, registration of database users, examples of PV system performance analysis, announcements of national and international workshops, links to other relevant websites.

SUBTASK 1: International Database

Task 2 will continue to **collect and import new plant** and monitoring data from their country and from other possible sources. Data collection focuses on additional data sets from already existing PV systems, new types of PV systems and PV systems in a new countries. An enhanced effort will be made to get representative PV plant data of different climatic regions and to fill in the gaps of the current database.
Task 2 will continually **review and upgrade the Performance Database**. The development and production of regular updates of the Performance Database depend on new entries of collected data. Updates containing the collected data (6 MB), but not the complete programme (47 MB), will be available for downloading from the Task 2 website. Registered users will be informed about the release of database updates and can incorporate the new database into the existing programme.

The Task 2 Performance Database will be promoted as a tool for planning, sizing and improving PV systems with respect to operational performance and reliability. For **database promotion**, Task 2 intends to use public websites of IEA-PVPS and Task 2, to place articles in international newsletters, journals and magazines, to present at conferences, seminars and workshops and to access specific target groups and contacts outside PVPS.

SUBTASK 2: Evaluation of PV Systems

The activities of PV system performance analysis will be continued. The PV systems under analysis will be grid connected PV systems and hybrid stand-alone PV systems. Performance indicators will be identified and performance results will be presented in standard format. Task 2 will produce summary report updates on performance results of new PV systems and will publish them on the Task 2 website.

Task 2 has recognised that the Performance Database cannot provide all information necessary for the improvement of the current PV system technology. For this reason new activities are being defined including an overview of irradiation data, guidelines to predict real PV output, recommendations on improving operational reliability of PV components, and guidelines for PV components sizing.

SUBTASK 4: Improving PV System Performance

Task 2 will continue the work on PV systems performance assessment checking the relevance of matching factor and usage factor and defining the minimum parameters required for performance assessment. A specific methodology on sizing of PV hybrid systems, based on the analysis of operational data, will be developed to improve PV hybrid system operation. Other case studies will be selected to enlarge the EMS analysis and give the results the widest signification possible.

INDUSTRY INVOLVEMENT

Task 2 benefits from its cooperation with PV industries, electricity utilities and other agencies, both for collection and analysis of PV system data and for dissemination of technical information to target audiences.
PV industries, utilities and engineering & consulting companies are important and well-represented user groups of the Task 2 Performance Database, who are gaining valuable information from the data provided (see also Figure 3).

TABLE 1 - LIST OF PARTICIPATING COUNTRIES, TASK PARTICIPANTS IN 2001 AND THEIR ORGANISATIONS

COUNTRY	PARTICIPANT	ORGANISATION
Austria	Mr. Michael Heidenreich	Arsenal Research
France	Mr. Didier Mayer	Ecole Des Mines de Paris
Germany	Mr. Reinhard Dahl (OA)	Projekttraeger Juelich (PTJ) Forschungszentrum Juelich GmbH
	Ms. Ulrike Jahn	Institut für Solarenergieforschung GmbH Hameln / Emmerthal (ISFH)
	Mr. Wolfgang Nasse	Solar Engineering GmbH
Italy	Mr. Salvatore Castello	ENEA C.R. Casaccia
Japan	Mr. Koichi Sakuta	National Institute of Advanced Industrial Science and Technology (AIST)
	Mr. Tadatoshi Sugiura	JQA Organization
The Netherlands	Mr. Nico van der Borg	ECN
Switzerland	Mr. Luzi Clavadetscher Mr. Thomas Nordmann	TNC Consulting AG TNC Consulting AG

TABLE 2 - MEETING SCHEDULE (2001 AND PLANNED 2002)

TASK 2 MEETING	DATE	PLACE
4th Task 2 Participants` Meeting	19-20 March, 2001	Sophia-Antipolis, France
5th Task 2 Participants` Meeting	19-22 September, 2001	Yokohama, Japan
6th Task 2 Participants` Meeting	21-23 March, 2002	Naples, Italy
7th Task 2 Participants` Meeting	11-14 September, 2002	Vienna, Austria

KEY DELIVERABLES (2001 AND PLANNED 2002)

An IEA-PVPS Task 2 workshop on "Operational Performance, Reliability and Promotion of Photovoltaic Systems" was held in Munich, Germany, on 24 October 2001, in conjunction with the 17th European PV Solar Energy Conference & Exhibition. The workshop attracted more than 70 participants from 20 countries and different sectors.

The following deliverables have been developed and published during 2001:

- PVPS Task 2 Performance Database programme, version 1.19 (45 MB), July 2001, available on CD-ROM and by Internet downloads.
- Database with collected data from 290 PV systems, released in July 2001.
- Instruction manual for Performance Database, July 2001.
- Installation guide for Performance Database, July 2001
- Brochure: IEA-PVPS Task 2, September 2001.

The following report was published during 2001:

- Workshop proceedings on "Operational Performance, Reliability and Promotion of Photovoltaic Systems"," Munich, Germany, October 2001.

The following internal document was produced during 2001:

- PVPS Task 2 workshop PC presentations (Power Point), October 2001.

Public reports and other materials are available on the PVPS website http://www.iea-pvps.org.
The Performance Database programme can be downloaded from the Task website "http://www.task2.org."

TASK 3 - USE OF PHOTOVOLTAIC POWER SYSTEMS IN STAND-ALONE AND ISLAND APPLICATIONS

Titchmardh Lock: PV powered lock gate, UK. (source: IT Power)

OVERALL OBJECTIVE

The main objective of Task 3 is to improve the technical quality and cost-effectiveness of PV systems in stand-alone and island applications. This work considers all types of stand-alone photovoltaic systems, ranging from small PV kits to power stations supplying micro-grids.

To this end, a detailed new work plan has been approved by the Executive Committee in May 1999.
The main objective of the Task 3 extension programme is to contribute to the cost reduction of systems through collaborative activities focused on technical issues, divided into the two main following categories:

1. Subtask 1: Quality Assurance: Quality Assurance Schemes for Improved Reliability and Lower Global Life Cycle Costs
2. Subtask 2: Technical Issues: Technical Recommendations for the Cost Reduction of Systems

The main targets are technical groups such as:

- Project developers
- System designers
- Industrial manufacturers
- Installers
- Utilities
- QA organisations
- End users

The main method of work consists of a practical approach through identification, selection, and observation of case studies. After the analysis of the collected data, a collaborative work programme will be developed to make recommendations. In relation to the large range of stand-alone PV applications, it is necessary to take into account systems operating in industrialised and southern countries as illustrated inwith the attached pictures.

SUBTASK 1: Quality assurance

Activity 11: Critical Review of Implementation of Quality Assurance Schemes

Objective

All phases in the life cycle of stand-alone PV systems must be considered as potential sources of failure to ensure the good management of the quality of installed systems. To provide both end-users and programme managers with guidance for the quality assurance of systems, projects and programmes, participants are working on **methodological and practical aspects** concerning quality assurance.
For this topic, participants aim to develop **quality assurance schemes** that will lead to a warranty of service for the end user at reasonable costs (that means as low as possible).

Major Activities in 2001

A comprehensive study of international guidelines has been undertaken in 2000. The results of these surveys form the basis for a document which is available on the Task 3 website. Following this action, Task 3 participants completed this first basis on current guidelines as developed in their respective countries.

Activity 12 : Technical Aspects of Performance Assessment on Field

Objective

The implementation of Quality Assurance Procedures is often difficult in the field, particularly when the procedures are too complicated or otherwise inappropriate. This is especially the case when considering the installation, operation and maintenance phases.
In addition, the performance assessment of installed stand-alone PV systems depends on both technical and non technical criteria, such as economic and social criteria.
Even when methodological and conceptual aspects of the performance assessment have been implemented, realistic methods and concrete supports must be recommended for use in the field and laboratory.

Major Activities in 2001 and Foreseen Activities in 2002

Preparation of recommendations dedicated to "Quality Management" is under way.
The aim is to provide new project managers with realistic and efficient recommendations, based on Task 3 experience, concerning management of the quality of SAPV systems. The main objective is to create awareness for the potential actors in that more attention must be given to the management of the quality of a system than to simply to manage a good design ; a lot of effort must be implemented in each step of a project.
It is planned to produce the final document in 2003, including a collection of quality management data as observed in the field: real practices, success and failure stories collected through feed back from case studies.

Deliverable under Preparation

- Management of the Quality of SAPV Systems: Recommended Practices

SUBTASK 2: Technical issue

Activity 21: Hybrid Systems

Objective

This subtask aims to be a technical contribution to cost reduction through standardisation and modularity in order to facilitate large scale dissemination of PV Hybrid systems.

Heliodor: lighting system, Germany.
(source: Solare Beleuchtungssysteme)

As learned from experience, relatively high costs of remote maintenance are a major factor in the global life cycle cost of hybrid systems.

Technical development should concentrate on the following recommendations:

- Encourage modularity to facilitate industry expansion and reduce the capital cost of systems
- Monitoring system performance to help reduce the maintenance costs
- Promote controller and user interfaces able to reduce operation complexity and maximise fuel savings

Major Activities in 2001

To address the current work plan, Task 3 needed to be able to analyse the performance of case studies to determine what comprises a successful, or conversely an unsuccessful installation. This requires a monitoring process conducive to an equitable comparison of system performance. In this way, the activity of experts was to prepare proposals for performance indicators of SAPV systems and monitoring guidelines, setting out how to equitably monitor system performance for a range of SAPV systems.

The current work is to produce "Guidelines for Performance Assessment of SAPV Systems and Guidelines for Monitoring Equipment and Protocols for SAPV Systems." The objectives of this cooperative work are:

- To prescribe a process that, if followed, will reassure investors, project managers, performance auditors, equipment manufacturers, and servicing firms, that the performance data they use are robust, equitable and representative
- To underpin a case study record that provides prospective PV users with relevant, comparative information about PV technology and its applications
- In conjunction with the above, to establish a more qualitative set of performance indicators that will enable the layperson to shortcut the scientific approach to performance assessment

One hand, the choice of a system to service specific need is complicated.
In the first place, no two applications are identical, while in the second, there is a large range of available system architectures from which to choose. When the lack of broad community experience with the relevant technologies, and the immature nature of the supporting industry to the situation are added, the need for a simple set of guidelines to help prospective users choose or identify the technologies that might be appropriate for their situation becomes obvious. That's why guidelines are prepared to assist people with a limited background in this industry; to navigate them through the mine field of market hype and misinformation, and, to determine for themselves, a system configuration that approximates their specific needs. Final results under preparation are "Guidelines for Selecting SAPV Systems" whose objectives are to provide a facility that assists prospective users of PV and, to identify the system configuration that reflects the best commercial practice for their application.

In collaboration with the Photovoltaic Program of the CANMET Energy Diversification Research Laboratory (CEDRL), Task 3 participants were involved through presentations in the workshop, "PV Horizon," held in Montréal on September, 10, 2001, which was dedicated to the "International Experience with Hybrid Systems" and "R&D Opportunities for Hybrid Systems."

Deliverables under Preparation

- Guidelines for Performance Assessment of SAPV Systems
- Guidelines for SAPV Selecting Systems

Activity 22: Storage

Objective

This subtask aims to be a technical contribution to cost reduction of the storage function in PV and PV Hybrid systems by decreasing investment costs and increasing performance (capacity, lifetime, etc.) through design, selection procedures of storage systems, and energy management recommendations.
One of the main objectives of this activity is to show that there should be a correlation between the type of batteries and the type of application and to recommend, in a situation of call for tender, how to specify the best battery for a given application.

Major Activities in 2001

Collaborative work was developed to assess various strategy regulations.

A technical work programme was undertaken concerning the test of batteries to be used in SAPV systems. The main objectives are here:

- To provide project managers involved in a battery selection process for PV applications with data
- To focus the activities of laboratories involved in battery testing on a few selected test procedures
- To promote the setting up of a database to make more data available and to make them more visible

Water desinfection system, Uganda" - source: Kassel University

The objective of another activity is to gather information of possible alternatives to lead-acid batteries for short, middle and long term storage (main performance, field of applications, estimated costs), some Task 3 participants are involved in a project whose aim is to build a state of the art of the existing and innovative technologies in the context of renewable energies.

Deliverables under Preparation

- Guidelines for selecting batteries to be used in SAPV systems

Major Foreseen Activities in 2002

- Review on alternative technologies to lead-acid batteries for storage function in SAPV systems (continued)

Activity 23: Load/Appliances: Load Management and New Applications

Objective

This subtask aims to be a technical contribution to cost reduction by showing the cost efficiency of a good load management strategy and well adapted appliances designed for low energy power systems.
This subtask is an integrating issue which calls for inputs from the other technical issues (2.1 and 2.2) but also from the economic and possibly social analysis coming from Task 9, in order to be able to install a PV system that is not only technically good but also credible and well accepted by the end user.
The goal is also to propose design recommendations for very dedicated applications of PV systems.

Major Activities in 2001

A survey of main recurrent technical difficulties with DC and AC appliances as seen in the field was achieved. This survey considers some poor compliance of the technical characteristics of DC and AC appliances with the power and energy management design of a stand-alone PV system. The cooperative work is to share experience by collecting many examples (of difficulties experienced and adopted solutions) as really seen in the field, that could be used as a reference by designers, installers and operators to prevent problems on existing or future systems. A paper was presented at the 17th European PV Conference in Munich. A document called , "Problems Related to Appliances in Autonomous PV Applications," has been produced and is available on the Task 3 website.
Another activity has been launched relative to the Demand Side Management (DSM). DSM for Renewable Energy systems involves the change of energy use habits of consumers not only by using high efficiency appliances, decreasing the peak of the load curve, but also by using energy in a way that the load is well matched with the renewable source. This is different from classic DSM methodologies where the objective is essentially to have more or less a flat load curve by smoothing daily peaks and valleys of shifting energy-use to off-peak hours.

Deliverable under Preparation

- DSM Management in SAPV Systems

OTHER ACTIVITIES

Other Activities in 2001

- Update of Task 3 website : www.task3.pvps.iea.org
- Co-operative work with Task 9

Foreseen Activities in 2002

- Contribution to a Workshop on Hybrid Systems, September 2002

MEETING SCHEDULE

Meetings Held

14th Task 3 Experts Meeting, February 1999, Australia
15th Task 3 Experts Meeting, September 1999, Sweden
16th Task 3 Experts Meeting, February 2000, Portugal
17th Task 3 Experts Meeting, September 2000, France
18th Task 3 Experts Meeting, March 2001, Norway
19th Task 3 Experts Meeting, September 2001, Canada

Meetings Planned

20th Task 3 Experts Meeting, March 2002, Spain
21th Task 3 Experts Meeting, September 2002, Japan

COUNTRY	NAME	ORGANISATION
Australia	Keith Presnell	Power & Water Authority NT
Canada	Dave Turcotte	CANMET
France	Philippe Malbranche	GENEC
	Philippe Jacquin (OA)	PHK Consultants
Germany	Ingo Stadler	IEE-RE
Italy	Francesco Minissale	Conphoebus
Japan	Noboru Yumoto	YN International
Norway	Arve Holt	IFE
Portugal	Antonio Joyce	INETI
Spain	Xavier Vallve	TTA
Sweden	Peter Krohn	Vattenfall Utveckling AB
Switzerland	Michel Villoz	Dynatex SA
United Kingdom	Alison Wilshaw	IT Power Ltd

TASK 5: GRID INTERCONNECTION OF BUILDING INTEGRATED AND OTHER DISPERSED PHOTOVOLTAIC POWER SYSTEMS

OVERALL OBJECTIVE

The objective of Task 5 is to develop and verify technical requirements, which will serve as the technical guidelines for grid interconnection with building-integrated and other dispersed PV systems. The development of these technical requirements will include safety and reliable linkage to the electric grid at the lowest possible cost. The systems to be considered will be those connected with a low-voltage grid, which are typically of a size between one and fifty peak kilowatts.

MEANS

Participants have carried out five subtasks, subtask 10, 20, 30, 40 and 50 in order to achieve these objectives.
The objectives of each subtask are as follows:

Subtask 10: Review of Previously Installed PV Experiences.
To review existing technical guidelines, local regulations and operational results of grid interconnection with building integrated and other dispersed PV systems to aid subtask 20: in defining existing guidelines and producing concepts for new requirements and devices.

Subtask 20: Definition of Guidelines to be Demonstrated.
Utilizing the results of subtask 10 and a questionnaire, existing technical guidelines and requirements to be demonstrated will be defined, and concepts for new requirements and devices will be developed, with safety, reliability, and cost reduction taken into consideration.

Subtask 30: Demonstration Test Using Rokko Island and/or Other Test Facilities.
To evaluate by demonstration tests the performance of existing and new technical requirements and devices defined in subtask 20.

Subtask 40: Summarising Results.
To summarise the results of Task 5 and to produce a general report for all participating countries of Task 5 and for ExCo members.

Subtask 50: Study on Highly Concentrated Penetration of Grid Interconnected PV Systems.
To assess the net impact of highly concentrated PV systems on electricity distribution systems and to establish recommendations for both distribution and PV inverter systems to enable widespread deployment of solar energy.

OVERVIEW OF PAST ACTIVITIES

Subtask 10

Survey of existing guidelines and regulations for grid connection of PV systems and the difference of electrical distribution systems in Task 5 participating countries were completed as the Task 5 internal report opened to IEA member countries. The report on inverter and related protection equipment was distributed to expert members as the Internal Task Working Document. The summary of PV operating experience from participating countries was included in the Task 5 summary report.

Subtask 20

Research results on subjects important for interconnection of PV systems were completed as an official IEA report. The following are the report contents for each subject.
Harmonics; Harmonic effects, present international rules and experimental results were summarised in the report.

AC-Module; Recent situations concerning R&D, commercial products and regulation on AC module in participating countries were summarised.

Multiple Inventers and AC Grid; Problems and countermeasures for voltage variation, reverse power flow, and grid short circuit fault were summarized in the report.

Grounding of Equipment in PV Systems; Standards and codes for each country for grounding requirements were summarised.

Ground-fault Detection and Array Disable for PV systems; Fire safety, grounding fault detection on DC side, etc. were summarised.

Over Voltage Protection; Over voltage due to indirect lightning strikes were analysed with consideration of the grounding structure of the PV system.

Islanding; Islanding prevention methods developed and adopted in each country were summarised in the report.

Electro Magnetic Compatibility; Standards and codes for electromagnetic emission were collected and summarised.

External Disconnect; Standards and codes of each country for the external disconnecting devices were collected and summarised.

Re-closing; Theory, problem, and experimental results for the effect of re-closing on PV systems were summarised in this report.

DC Injection and Isolation Transformer; Influences of DC injections on utility transformers were investigated by experiments.

Subtask 30

Demonstration tests for harmonics, islanding, PV output variation etc. were conducted using the Rokko Test Facility in Japan. The Subtask 30 report, summarising demonstration test results using the Rokko Test Facility was completed and published as an official IEA-PVPS report. Contents of the report include, harmonics caused by PV inverters, measurement of islanding, distribution line short circuit fault, AC/DC mixing fault, the effect of PV system output fluctuation and others.

Subtask 40

The summary report of Task 5 activities from 1993 to 1998 was produced as an official IEA-PVPS report.

The summary report is composed of:

- Executive Summary
- Summary of subtask activities
- Summary of subtask 10
- Summary of subtask 20
- Summary of subtask 30
- Future work recommendations (related to the following subtask 50 work)

Subtask 50

Surveys for the latest PV system grid interconnection technologies were conducted and reported. These surveys included PV system grid-interconnection and design guidelines or national standards, updated information of inverters and interconnection devices and PV system testing certification and utility inspection and maintenance method.

Research on islanding related problems has been conducted in highly penetrated PV systems conditions. The probability of load and PV system output matching was determined using real measurement and the risk of islanding was defined. Islanding detection method and test circuit for islanding detection performance were summarised and reported.

Important factors to decide on the limit of PV system penetration in distribution networks were listed and analysis based on distribution line voltage limit was conducted. Measures to stretch the limit of PV penetration and some financial aspects of PV penetration were also discussed.

Power value and capacity value of PV system penetration were evaluated using different customer load profile.

OVERVIEW OF 2001 ACTIVITIES

Subtask 50

51. Reporting of PV System Grid-Interconnection Technologies

The survey result for PV system grid-interconnection and system design guidelines or standards of Task 5 participating countries was summarised and reported. The survey result shows the tendency that PV specific or inverter specific interconnection guideline is becoming common.

The survey result for updated information of inverters and interconnection devices was summarised. High performance with high conversion efficiency, low harmonic current generation and good power factor operation have been realized, while cost, volume and weight reduction have been achieved.

The survey result for certification of PV system components and grid-interconnected PV systems was summarised. Certification test subjects and test sequence were recommended in the final draft of the report.

52. Research on Islanding

The result of measurement and calculation for load and PV output profile was summarized and reported. These calculation results are used to determine the probability of islanding, because islanding occurs at the matching condition of load and PV output (for both active power and reactive power). The result suggests that if the total capacity of PV systems is under the minimum load (around 20% of peak load) of the distribution line, the probability of islanding is zero. Even if PV systems are penetrated beyond this level, the possibility of load matching is very small; about 1.0E-6 to 1.0E-5. The probability of islanding is calculated by multiplying the possibility of load matching and the possibility of loss of main (for example 6.3E-8). Therefore, the probability of islanding is far more reduced. The risk of islanding was also calculated and we found that the risk of islanding does not significantly increase the risk that already exists. The quality of PV system installation and inverter safety integrity level affects the level of risk.

Surveys for islanding detection method and islanding detection test circuit were conducted and reported. Various kinds of islanding detection methods were listed with principal, strengths and weakness and characteristics of non-detection zones. Several kinds of anti-islanding test methods and test circuits were also summarised for further consideration of standardization of test circuit.

53. Performance of High Penetrated PV systems

54. Capacity of PV Systems

Factors to decide on the limit of PV system penetration in distribution networks were listed and an analysis based on distribution line voltage limit was conducted. Considering the distribution system line voltage control operation, there will be no problem if the PV systems are penetrated below minimum load level (typically 20% to 25% of distribution line capacity). Measures to stretch the limit of PV penetration and some financial aspects of PV penetration were also discussed. Distribution system planning considering PV system penetration and demand side management using PV system will be the future key to enhance PV penetration.

Power value and capacity value of PV system penetration were evaluated using different customer load profiles. These values strongly depend on load profile and climate condition. Therefore, it will be difficult to make a general conclusion for the added value of PV systems.

Task 5 Workshop – The Impact of PV Penetration in Distribution Networks

A two-day Task 5 workshop was held on January 24 and 25, 2002, at Arnhem, The Netherlands. This workshop was the last activity of Task 5. Seventy five participants from fourteen countries (Australia, Austria, Belgium, Canada, Denmark, France, Germany, Italy, Japan, The Netherlands, Portugal, Switzerland, United Kingdom and the United States of America) took part in the workshop.
In the workshop, Task 5 findings for the summary of islanding detection methods, probability of islanding and risk analysis for islanding were presented and discussed on the first day. On the second day, PV related guidelines and standards, inverter technology, impact of PV penetration and value of PV were presented and discussed.

SUMMARY OF WORK PLANS FOR THE COMING YEAR

Task 5 finished work at the end of January 2002. The complete report will be ready for submission to the ExCo for their publication approval by the end of March 2002.

INDUSTRY INVOLVEMENT

Members from utilities and inverter manufactures participated in Task 5 as experts.

Data collection from utilities and manufacturers have been undertaken to carry out Task 5 activities.

REPORTS PRODUCED IN 2001

Report IEA PVPS T5-04: 2001; "PV System Installation and Grid Interconnection Guidelines in Selected IEA Countries"

The following reports will be submitted to the ExCo and will be published in early 2002:

- Report IEA PVPS T5-05: 2002; "Grid Connected PV Power Systems: Survey of Inverter and Related Protection Equipment"
- Report IEA PVPS T5-06: 2002; "International Guidelines for the Certification of PV System Components and Grid Connected PV Systems"
- Report IEA PVPS T5-07: 2002; "Probability of Islanding in Utility Networks Due to Grid Connected PV Power Systems"
- Report IEA PVPS T5-08: 2002; "Risk Analysis of Islanding of PV Power Systems within Low Voltage Distribution Networks"
- Report IEA PVPS T5-09: 2002; "Evaluation of Islanding Detection Methods for PV Utility Interactive Power Systems"
- Report IEA PVPS T5-10: 2002; "Impacts of Power Penetration from PV into a Power System"
- Report IEA PVPS T5-11: 2002; "Power Value and Capacity Value of PV Systems"

MEETING SCHEDULE

Past Meetings(1/2001-1/2002)

The 16th Expert Meeting was held on 5-7 March 2001, in the UK

The 17th Expert Meeting (Final Task 5 Meeting) was held on 21-23 January 2002, in The Netherlands.
(with Task 5 Workshop on 24-25 January 2002)

TASK 5 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANIZATION
Australia	Phil GATES	Energy Autralia
Austria	Gerd SCHAUER	Verbundgesellschaft
	Christoph PANHUBER	Fronius KG Austria
Denmark	Arne Faaborg POVLSEN	Elsamprojekt A/S
Germany	Hermann LAUKAMP	FhG-ISE
Italy	Francesco GROPPI	Enel S.p.A.
Japan	(Task V OA) Tadashi KANBAYASHI	NEDO
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	James THORNYCROFT	HGA Ltd.
United States	Ward BOWER	Sandia National Labs.

IEA PVPS TASK 7 - PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

1. OVERALL OBJECTIVES

The objective of Task 7 is to enhance the architectural quality, the technical quality and the economic viability of PV systems in the built environment. The objective is also to assess and remove non-technical barriers for their introduction as an energy-significant option.

It is expected that successful integration of PV systems into the built environment (BIPV) will contribute significantly to the future spread of PV.

For this active involvement of urban planners, architects and building engineers is required. Task 7 motivates the collaboration between these groups and PV system specialists, utility specialists, PV and building industry and other professionals involved in photovoltaics.

Task 7 considers all grid connected systems other than classified as "ground based arrays." Primary focus of this Task is on the integration of PV into the architectural design of roofs and facades of residential, commercial and industrial buildings and other structures in the built environment (such as noise barriers, parking areas and railway canopies), and on other market factors, both technical and non-technical, that need to be addressed and resolved before wide spread adoption of PV in the built environment will occur.

Task 7 officially started on January 1, 1997 and lasted to the end of 2001. The finalisation of the Task 7 products will take place in the first half of 2002.

2. MEANS

In order to achieve the overall objectives, participants carry out work in four Subtasks:

- Subtask 1: Architectural Design of Photovoltaic Power Systems in the Built Environment;
- Subtask 2: Systems Technologies for Photovoltaic Power Systems in the Built Environment;
- Subtask 3: Non-technical Barriers in the Introduction of Photovoltaic Power Systems in the Built Environment;
- Subtask 4: Demonstration and Dissemination of Photovoltaic Power Systems in the Built Environment.

3. SUBTASK 1: ARCHITECTURAL DESIGN OF PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

3.1 Objective

Participants work on the improvement of the architectural design of PV systems as an integral element in buildings and other structures in the built environment. For this purpose existing PV projects are documented. In addition, case studies are followed and evaluated by the Task Participants. Many of these case studies are realised as demonstration projects.

A selection of outstanding examples (both from existing projects as well as from the case studies) will be published as a book. As a sideline, design tools for architects are developed.

3.2 Activities

3.2.1 Documentation of high quality projects
3.2.2 Case studies
3.2.3 Book of examples
3.2.4 Design tools

3.3 Major Activities in 2001

Documentation of High Quality Projects

The Task 7 BIPV Projects Database of 400 BIPV projects are now up and running. It is accessible via http://www.pvdatabase.com via the Task 7 website and is open to the public.

Case Studies

Updating the progress of these case studies will remain crucial for the success of this activity. Collaboration and fine tuning with Task 23 of the IEA Solar Heating and Cooling Programme (working on the same issue) is in process.

3.4 Major Activities Foreseen for 2002

Book of Examples

A high quality book (250 p.) will be presented in the beginning of 2002: "Building with Solar Power." The book will focus on PV and architecture, and contain examples and reference information for architects. The book will also include CD-ROMS of PVSystems and of the training and education package.

Case Studies

Publication of the case study report is foreseen in early 2002. The Italian Environmental Ministry has expressed their interest in publishing in Italian version of the IEA case study report.

4. SUBTASK 2: SYSTEMS TECHNOLOGIES FOR PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

4.1 Objectives

Participants work on the development of new concepts for photovoltaic power systems in the built environment that can enhance the electrical performance or the performance of the PV system as a building component. New concepts, developed by the Participants shall enhance market opportunities for the industry. This Subtask aims for a number of standardised and certified PV elements for integration in buildings and other structures in the built environment. The Subtask will also provide a number of options to effectively utilise the PV electricity and to connect PV systems safely and reliably to the electricity grid, as far as this topic is not addressed by Task 5 of the PVPS Implementing Agreement.

4.2 Activities

4.2.1 Commercial buildings
4.2.2 Residential buildings
4.2.3 Non-building structures
4.2.4 Guidelines and certification
4.2.5 PV/T (PV and thermal systems)
4.2.6 New electrical concepts
4.2.7 Reliability
4.2.8 Interconnection issues
4.2.9 Electrical design issues

4.3 Major Activities in 2001

Building Integration Concepts

A workshop on building integration concepts for PV products was held in May 2001, in conjunction to the Sustain 2001 Trade Fair in Amsterdam. Over 50 experts attended, of which approximately half from the Netherlands, the other half from other countries.

PV Building Product Database

As part of www.pvdatabase.com a module of PV products was added, comprising about 100 BIPV products and its manufacturers and application features.

Non-Building Structures

The ExCo approved report was disseminated with 220 copies for free distribution.

Reports in Preparation of Subtask 2

- Non-building structures: a report on integration of PV in non-building structures in the built environment is going to be integrated in the book "Building with Solar Power."
- PV/T: a report on technologies and systems for PV/T (PV and thermal systems).
- Electrical concepts: are going to be part of the book.
- Reliability: a report on reliability of PV systems.
- Interconnection issues: a report will be published.
- Electric designs issues: a report will be published, together with the case study report.

4.4 Major Activities Foreseen for 2002

Finalisation of the reports on technical issues is foreseen during the first months of 2002.

5. SUBTASK 3: NON-TECHNICAL BARRIERS IN THE INTRODUCTION OF PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

5.1 Objectives

Participants assess the non-technical barriers to be removed to make PV in the built environment an energy-significant power supply option. The purpose of this Subtask is to identify the barriers on one side and the (technical, economic, market) potential of PV in the built environment on the other. The main result of this Subtask will be an executive IEA report on strategies for barrier removal and the utilisation of the PV potential.

5.2 Activities

5.2.1 Barrier assessment
5.2.2 Potential
5.2.3 Economics
5.2.4 Strategies

5.3 Major Activities in 2001

An Executive Summary Report, "Institutional Issues," was prepared.

5.4 Major Activities Foreseen for 2002

Finalisation and dissemination of the ESR "Institutional Issues."

6. SUBTASK 4: DEMONSTRATION AND DISSEMINATION OF PHOTOVOLTAIC POWER SYSTEMS IN THE BUILT ENVIRONMENT

6.1 Objectives

The results of the other Subtasks are brought to the market by dissemination of collected information and the demonstration of new concepts. Demonstration of mounting and system concepts takes place through the EPFL Demosite. Results are disseminated by the use of different media (ranging from papers, books, and brochures to new media such as a CD-ROM or a WWW-site).
Dissemination will also occur through the second and third International Solar Electric Buildings Conferences and national workshops in conjunction with the semi-annual meetings of the Task. Furthermore, the possibility of a training and education program is assessed.

6.2 Activities

6.2.1 Demosite
6.2.2 Conference
6.2.3 Competition
6.2.4 Dissemination
6.2.5 Training and Education

6.3 Major Activities in 2001

Demosite

The IEA PVPS Task 7 demosite maintained its position as the demonstration centre for PV building integration products. Systems demonstrated at the Demosite are accessible via www.demosite.ch.

Conference
The attempts to organise the 3rd International Solar Electric Building Conference in The Netherlands failed. However, the outline of the 'would be' conference may well be used as a possible 'kick-off' conference of a possible Task 10. The conference was meant to focus on:

1. PV in the green buildings; addressing green building issues and a target audience of building experts, building industries, architects, local governmental organisations, etc. vs.

2. PV in green energy concepts; addressing utility programmes & financing issues and a target audience governmental policy markets, associated experts, utilities etc.

Training and Education
Work is in progress to establish accredited training courses on BIPV before the end of 2001. A standard programme for such courses and minimum attainment levels will be completed in 2002. A CD-ROM is in preparation.

6.4 Major Activities Foreseen for 2002
Completion of the Training and Education Package.
Organisation of an event at the PV for Europe conference in Rome, 7-11 October 2002. This event is projected instead of the 3rd Solar Electric Buildings Conference that was foreseen for July 3-4, in Amsterdam.
New format for the task 7 website by a division in architectural, technical and non-technical issues.

7. DELIVERABLES
7.1 Key Deliverables of 2001
- Internet: Database of more than 400 BIPV projects and over 100 BIPV products

7.2 Key deliverables foreseen for 2002
- Internet: database of BIPV products
- Book: Building with Solar Power (BIPV architectural book)
- Report: PV/T, technologies and systems for PV/T
- Report: new and innovative electric concepts for BIPV systems (part of the book)
- Report: Reliability, a survey on the reliability of PV systems
- Report: Electric Design Issues; guidelines for the electric design of BIPV systems (part of the book)
- Report: the BIPV potential in IEA member countries (part of the book)
- Executive Summary Report: Institutional Issues
- Package: an IEA training course for PV designers

8. PARTICIPANTS
Currently there are 14 countries participating in Task 7, with representatives from all targeted groups: architects, building and PV industry, PV and building specialists and utilities. A list of participants is shown in the table below.

9. TASK MEETINGS
9.1 Meetings in 2001
9th Expert Meeting
March 8-9, 2001
Freiburg, Germany

10th Expert Meeting, incl. Joint Expert Meeting with Task 2.
17-21 September 2001
Tokyo, Japan

9.2 Meetings in 2002
Final Conference
Autumn, 2002
Rome, Italy

10. CONTACT INFORMATION
Operating Agent ad interim
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Ecofys, Utrecht, the Netherlands
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Websites
Task 7 website: www.task7.org
Task 7 demosite: www.demosite.ch
PV Projects database: www.pvdatabase.com

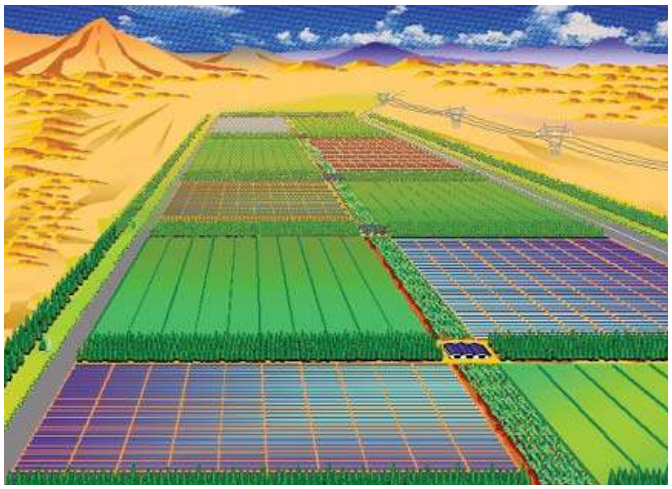
TABLE: LIST OF TASK 7 PARTICIPANTS

COUNTRY	PARTICIPANT	ORGANIZATION
Australia	Deo Prasad Mark Snow	National Solar Architecture Research Unit National Solar Architecture Research Unit
Austria	Reinhard Haas Karin Stieldorf Heinrich Wilk	Technische Universität Wien Inst. für Hochbau für Architekten Energie AG Oberösterreich
Canada	Per Drewes Raymond Cole	Sol Source Engineering University of British Columbia
Denmark	Kaj Isaksen Henrik Sørensen	VELUX Esbensen Consulting Engineers
Finland	Peter Lund	Helsinki University of Technology
Germany	Ingo Hagemann Hermann Laukamp	Architekturbüro HAGEMANN Fraunhofer-Institut für Solare Energiesysteme
Great Britain	Rod Hacker David Lloyd Jones Donna Munro Paul Ruyssevelt	Halcrow Gilbert Associates Studio E Architects Energy for Sustainable Development Energy for Sustainable Development
Italy	Cinzia Abbate Niccolo Aste Valerio Calderaro Angelo Sarno	Officine di Architettura di Cinzia Abbate Politecnico di Milano University of Rome/Fac. Arch. ENEA
Japan	Ito Tadashi Shogo Nishikawa Jiro Ohno Hideji Osawa	Kajima Corporation Kandenko Co., Ltd. Nihon Sekkei Inc. NEDO
Spain	Nuria Martín Chivelet	Ciemat-IER
Sweden	Mats Andersson	Energibanken
Switzerland	Christian Roecker Daniel Ruoss Peter Toggweiler	EPFL -LESO-PB ENECOLO ENECOLO
The Netherlands	Henk Kaan Tjerk Reijenga Frederik Leenders Tony Schoen Michiel van Schalkwijk	Energieonderzoek Centrum Nederland BEAR architecten Ecofys Ecofys (until 2002) Ecofys (starting 2002)
USA	Patrina Eiffert Steven Strong	National Renewable Energy Laboratory Solar Design Associates Inc.

TASK 8 - STUDY ON VERY LARGE SCALE PHOTOVOLTAIC POWER GENERATION SYSTEM

OVERALL OBJECTIVES

The objective of Task 8 is to examine and evaluate the potential of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems, which have a capacity ranging from multi-megawatt to gigawatt, by identifying the key factors that enable VLS-PV system feasibility and clarifying the benefits of this system's application to neighbouring regions. The potential contribution of system application to protection of the global environment and renewable energy utilization in the long term also will be clarified. Mid- and long-term scenario options for making VLS-PV systems feasible in certain areas will be proposed.



MEANS

To complete the overall objectives, participants carry out three Subtasks in series:

Subtask 1: Conceptual Study of the VLS-PV System
Subtask 2: Case Studies for Selected Regions for Installation of VLS-PV system
Subtask 3: Comprehensive Evaluation of the Feasibility of VLS-PV system

SUBTASK 1: CONCEPTUAL STUDY OF THE VLS-PV SYSTEM

Objective

The conceptual configuration of VLS-PV systems is developed from the viewpoint of technological/economical feasibility and the life cycle of the systems. The criteria for selecting regions for case studies of the installation of VLS-PV systems are also identified and then the regions for case studies will be nominated.

Major Activities in the Past

Background data such as world energy and environmental issues, technology and market trend for photovoltaics have been collected. Both degradation issues and O&M experiences were discussed in depth.

Major Activities Planned for the Coming Year

The data acquisition activity to complete this Task 8 will be continued.

SUBTASK 2: CASE STUDIES FOR SELECTED REGIONS FOR INSTALLATION OF VLS-PV SYSTEM

Objective

Employing the results from Subtask 1, case studies on VLS-PV systems for the selected regions are undertaken. In the case studies, the effects, benefits and environmental impacts are evaluated.

Major Activities in the Past

Several case studies are in progress. Concerning the Gobi desert, a basic design for 100MW VLS-PV system was completed, and energy payback time (EPT), CO2 emission rate and generation cost were evaluated. Socio-economic impacts resulted from technology transfer of PV module fabrication were discussed for the Sahara case study. High concentration technology applied to the Negev desert was also investigated.

Major Activities Planned for the Coming Year

All the case study now in progress will be completed, and a rough case study for major deserts in the world will be developed.

SUBTASK 3: COMPREHENSIVE EVALUATION OF THE FEASIBILITY OF VLS-PV SYSTEM

Objective

Joint assessment of the results from the Subtask 2 is carried out by summarizing similarities and differences in the impact of VLS-PV system installation in different areas. Mid- and long-term scenario options that will enable the feasibility of VLS-PV system are proposed.

Major Activities in the Past

Some promising concepts for sustainable development and growth scenario of VLS-PV system were shown. These sustainable scenarios include decommissioning and recycling of the VLS-PV system, on-site production of PV modules with economical and financial aspects.

Major Activities Planned for the Coming Year

Mid- and long-term scenarios for sustainable growth of VLS-PV system will be concluded. And the final technical report including all the outputs from subtask 1, subtask 2 and this task will be completed.

OTHER ACTIVITIES

A half-day international symposium was held in Korea in June 2001, in conjunction with PVSEC-12. About 50 people joined this symposium from 13 countries. Korean media also took up this event as well as PVSEC-12. The symposium closed with great success.

Technical visit to the Gobi desert (at 6th Participants Meeting)

The 1st Mongolian Photovoltaic Conference (MOPVC-1) was held in the beginning of September 2001, at Ulan Bator, in conjunction with the 6th Task 8 meeting. Some of Task 8 participants contributed to give their invited speech on specific topics and chaired several sessions.

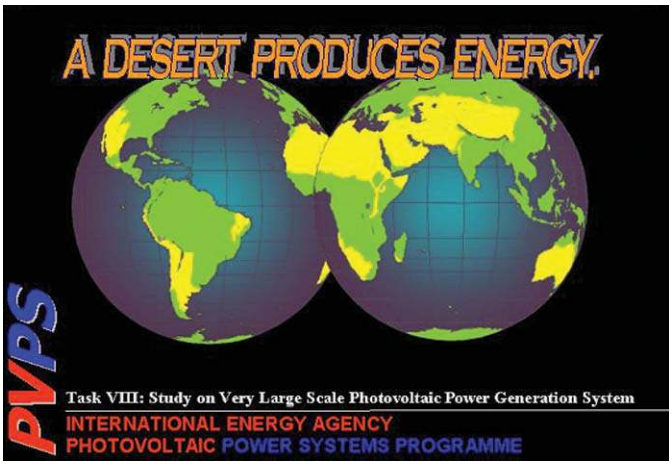
DELIVERABLES

Internal Publication

A Preliminary Analysis of Very Large Scale Photovoltaic Power Generation (VLS-PV) Systems: Report IEA-PVPS VI-5 1999:1

External Publication

"A DESERT PRODUCES ENERGY", official brochure of Task 8



PARTICIPANTS

As shown on the table, currently there are seven countries participating in Task 8, with representatives from research institutes, universities, utilities, PV consultancy and industry.

COUNTRY	PARTICIPANT	ORGANIZATION
Israel	Mr. David Faiman	The Ben-Gurion National Solar Energy Centre
Italy	Mr. Pietro Menna Mr. Fabrizio Paletta	ENEA ENEL-SRI PAL
Japan	Mr. Kosuke Kurokawa Mr. Kazuhiko Kato Mr. Keiichi Komoto Mr. Kenji Otani Mr. Isaburo Urabe	Tokyo University of Agriculture and Technology NEDO Fuji Research Institute Corporation AIST Photovoltaic Power Generation Technology Research Association
Korea	Mr. Jinsoo Song	Korea Institute of Energy Research
The Netherlands	Mr. Leendert Verhoef Mr. Peter van der Vleuten	Verhoef Solar Energy Free Energy International bv
Spain	Mr. Jesus Garcia Martin Mr. Alfonso de Julian Palero Mr. Luis Alberto Calvo	IBERDROLA IBERDROLA IBERDROLA
United States	Mr. David Collier	SMUD

MEETING SCHEDULE

Meetings Held

1st Task 8 Participants Meeting, June 28-29, 1999, Paris (France)
2nd Task 8 Participants Meeting, December 1-2, 1999, Utrecht (The Netherlands)
3rd Task 8 Participants Meeting, April 30, 2000, Glasgow (UK)
International Workshop, May 2, 2000, Glasgow (as a side event of EUPSEC-16)
4th Task 8 Participants Meeting, September 15-16, 2000, Sacramento (USA)
5th Task 8 Participants Meeting, June 9-10, 2001, Cheju Is. (Korea)
International Symposium, June 11, 2001, Cheju Is (as a side event of PVSEC-12)
6th Task 8 Participants Meeting, 2-4 September 2001, Ulan Bator (Mongolia)

Meetings Planned

7th Task 8 Participants Meeting, 27 February – 1 March 2002, Utrecht (The Netherlands)
8th (final) Task 8 Participants Meeting, 12-14 September 2002, Poland
International Symposium, 18 May 2003, Osaka, Japan (as a side event of WCPEC-3)

TASK 9 - DEPLOYMENT OF PHOTOVOLTAIC TECHNOLOGIES: COOPERATION WITH DEVELOPING COUNTRIES

Fig. 1 - Participants at Renewable Energy Seminar in Jakarta, March 2001.

OBJECTIVE

The conventional grid will not reach the estimated two billion people in developing countries without access to electricity in the foreseeable future. Renewable energy, and in particular PV, is uniquely attractive as a source of electricity for basic services and to contribute directly to the alleviation of poverty. PV systems can provide power for a wide range of applications including: systems for use in social services such as health clinics (refrigeration for vaccines, sterilisation and lighting), schools and community centres; domestic solar home systems (50-100 Wp) that provide electricity for 4 or 5 lights and low power appliances such as a radio; community battery-charging units; and water-pumping for provision of water for drinking, livestock and in some cases irrigation requirements. In many areas the technology is already cost-competitive with traditional alternatives, such as kerosene lamps and small diesel generators.

The objective of Task 9 is to increase the rate of successful deployment of PV systems (i.e., the rate of rural electrification) in developing countries. This will be promoted through enhanced cooperation and flow of information between the IEA PVPS Programme and developing countries, development banks, multilateral and bilateral aid agencies, and other targeted groups within developing countries. Task 9 draws upon other similar existing programmes and networks and builds upon these to provide an effective and efficient programme that addresses the needs and potential of developing countries, multilateral and bilateral donor agencies and development banks.

APPROACH

In order to achieve its objective, the collaborative work is organised into three Subtasks with the following objectives:

Subtask 10: Deployment Infrastructure: contributes to overcoming the critical barriers to widespread PV deployment and implementation through the development, dissemination and application of a series of Recommended Practice Guides (RPGs) to promote the necessary infrastructure requirements in developing countries.

Subtask 20: Support and Co-operation: stimulates awareness and interest amongst the multi- and bilateral agencies, NGOs and other target sectors on the technical and economic potential, opportunities and recommended practice of PV systems. This will enable decision-makers to obtain the expertise and knowledge that is required for appropriate PV system deployment.

Subtask 30: Technical and Economic Aspects of PV in Developing Countries: identifies the various technical supply options available and consider the issues relating to the preparation, design and implementation of PV deployment programmes.

The Experts appointed to the Task cover a broad range of experience, including technical PV experts, development economists, and other renewable energy technologists. The Task also includes representatives of the World Bank, the Global Environment Facility and the United Nations Development Programme, and developing country representatives are being encouraged to participate.

SUBTASK 10: DEPLOYMENT INFRASTRUCTURE

Aim

To develop, disseminate and apply a coherent series of Recommended Practice Guides (RPGs) to promote the necessary infrastructure requirements in developing countries to help overcome the critical barriers to widespread PV deployment and implementation.

Activities

11 Information Compilation and Analysis
12 Recommended Practice Guide Preparation
13 Dissemination and Promotion of Recommended Practice Guides

Activity 11: Information Compilation and Analysis

A draft of a document highlighting the issues pertinent to the large scale deployment of PV in developing countries has been prepared: PV Deployment in Developing Nations: An Overview. The document provides an overview of the issues to be considered when a developing country PV deployment programme is being developed. A series of case studies will provide supporting information. The issues are dealt with more thoroughly in the individual Recommended Practice Guides being developed in Activity 12. Nine case studies have been prepared by the Task Experts covering PV experience in China, India, Kenya, Kiribati, Morocco, Mozambique, Namibia, the Sahel and Zimbabwe.

Activity 12: Recommended Practice Guides

The drafting of five following Recommended Practice Guides is under way. Initial drafts were presented at the 4th and 5th Experts' meetings.

1. RPG: Institutional and Infrastructure Frameworks
2. RPG: Capacity Building
3. RPG: Deployment Models, Financing and Investment Mechanisms
4. RPG: Financing SHS in Developing Countries
5. RPG: Quality Assurance

Activity 13: Dissemination and Promotion of Recommend Practice Guides

This activity had not commenced in 2001.

Work Planned for 2002

Final drafts of the Recommended Practice Guides, Case Studies and Overview Document will be produced for presentation at the 6th Experts Meeting in Mexico.

The documents will be published on the Internet in Autumn 2002 and will be launched at an international workshop to promote the guides to as wide an audience as possible. Further dissemination of the documents will be through the internet and activities in Subtask 20. Any feedback received will be incorporated into revisions of the RPGs.

Fig. 2 - Solar home system in Mongolia.

Fig. 3 - Solar home system in Indonesia.

SUBTASK 20: SUPPORT AND CO-OPERATION

Aim

To stimulate awareness and interest amongst the target sectors on the technical and economic potential, opportunities and recommended practice of PV systems. This will enable decision-makers to obtain the expertise and knowledge that is required for appropriate PV system deployment.

Activities

21. Support to Multilateral and Bilateral Donors and Development Banks.
22. Cooperation with REWP and IEA/OECD

Activity 21: Support to Multilateral and Bilateral Donors and Development Banks

Task 9 organised a number of workshops in 2001 in collaboration with external organisations:

A Renewable Energy Promotion Seminar, March 2001 - co-ordinated by the Swiss State Secretariat for Economic Affairs and Task 9 for the ASEAN Centre for Energy in conjunction with the 4th Experts Meeting in Jakarta.

Financing Solar Home Systems in Developing Countries, March 2001 – coordinated by ISES and Task 9.

PV in Rural Electrification Workshop for CIDA, September 2001. The Canadian International Development Agency (CIDA) is a major bilateral donor. The workshop was targeted at CIDA staff with an interest in energy, environment and rural development and who are involved in the design and management of projects for rural areas of developing countries.

PV Horizon – PV Hybrid Systems Workshop, September 2001. PV Horizon was organised by the Photovoltaic and Hybrid Systems Program of the CANMET Energy Diversification Research Laboratory (CEDRL) in collaboration with Task 3.

The work of Task 9 was also presented at PV conferences in Germany, Korea and Mongolia.

Activity 22: Co-operation with REWP and IEA/OECD

Task 9 prepared a paper on behalf of the PVPS ExCo, which was submitted to the G8 Renewable Energy Task Force in October 2000. The PVPS submission to the G8 Task Force was well received and clearly influenced the first Final Report, which was presented to the G8 Heads of Government at their Summit meeting in Genoa in July 2001.

Task 9 was mandated by the ExCo to make a proposal for an Executive Conference provisionally titled: Renewable Energy for Rural Services. An initial proposal was drafted and submitted to the ExCo in February 2001. However, it is now unlikely that the Conference will take place as initially envisaged and alternatives are being investigated. One option being pursued is to combine this with the Village Power Conference, which is generally hosted by the World Bank and organised by the USA.

Work Planned for 2002

A series of further workshops are planned over the next three years. Two workshops are planned for 2002:

Swedish International Development Co-operation Agency.
Asian Development Bank

The following agencies have also been identified as host institutions for further workshops:

- World Bank Group, Washington
- United Nations Development Programme (UNDP), New York
- Asian Development Bank (ADB), Manila
- Inter-American Development Bank (IDB), in-country-office in a Latin American State
- African Development Bank (AFDB), Abidjan
- European Commission (EC), Brussels

In particular, identification of a suitable event to act as a vehicle to launch the RPGs will be carried out. The aim of such an event would be to act as a high profile event to launch the RPGs to promote them to as wide an audience as possible.

SUBTASK 30: TECHNICAL AND ECONOMIC ASPECTS OF PV IN DEVELOPING COUNTRIES

Aim

To investigate the techno-economic aspects and potential of PV systems in developing countries. The objectives are to identify the various technical supply options available and consider the issues relating to the preparation, design and implementation of PV deployment programmes.

Activities

Following a delay in identifying a leader for Subtask 30, the subtask is now on schedule with a revised work plan under the leadership of the USA. The subtask now has the following 2 activities:

31. Programme Design and Implementation
32. Proposal Preparation

Activity 31: Programme Design and Implementation

Activity 31 is considering the issues relating to the preparation, design and implementation of PV deployment programmes: the various technical supply options - stand-alone systems, diesel hybrid village/mini grid systems and grid-connected systems; and the availability and use of new analysis tools. This will provide guidance for programme planners on the various rural electrification approaches and the technical supply options available. A draft version of the Recommended Practice Guide, provisionally titled, "Programme Design and Implementation," was prepared in 2001.

Activity 32: Proposal Preparation

Activity 32 will provide guidance on the potential sources of finance for PV deployment programmes and the processes involved in accessing this finance. The processes by which finance can be obtained from the World Bank Group, bilateral donors, utilities etc will be identified and summarised in a Recommended Practice Guide, provisionally titled, "Proposal Preparation." The first draft of the guide has been prepared.

Work Planned for 2002

The first drafts of the two Recommended Practice Guides will be produced for presentation at the 6th Experts Meeting in Mexico.

The documents will be published in Autumn 2002 and will be launched, with the RPGs from Activity 10, at an international workshop. Further dissemination of the documents will be through the Internet and activities in Subtask 20.

Task Meetings

1st Experts Meeting, 14-16 October 1999, Utrecht, The Netherlands.
2nd Experts Meeting, 8-9 February 2000, Washington DC, The USA.
3rd Experts Meeting 2-3 October 2000, Jakarta, Indonesia
4th Experts Meeting, 26-27 March 2001, ASEAN Centre for Energy, Jakarta, Indonesia.
5th Expert Meeting, 12-13 September 2001, Ottawa, Canada.

Planned Meetings in 2002

6th Experts Meeting, 26-28 February 2002, Oaxaca, Mexico
7th Experts Meeting, September 2002, Manila, Philippines

TASK 9 PARTICIPANTS

COUNTRY	NAME	AFFILIATION
Australia	Gordon Thompson	CASE
Australia	Geoff Stapleton	GSES
Canada	Gerry Collins	CIDA
Denmark	Peter Ahm	PA Energy A/S
Denmark	Jean Paul Laude	DANIDA
Finland	Heikki Tikkanen	NAPS
Finland	Heikki Neuvonen	NAPS
France	Jean Louis Bal	ADEME
France	Anjali Shanker	IED
Germany	Rolf Posorski	GTZ
Germany	Klaus Preiser	Fraunhofer Institute
Italy	Roberto Vigotti	CESI
Japan	Takayuki Tani	Institute of Energy Economics
Japan	Kazuo Yoshino	Yoshino Consult
Japan	Takayuki Nakajima	Japan Photovoltaic Association
Japan	Hideo Senba	SunTechno
Netherlands	Li Hua	Novem
Switzerland	Alex Arter	ENTEC
UK	Bernard McNelis	IT Power
UK	Jonathan Bates	IT Power
USA	Mark Fitzgerald	ISP
USA	Roger Taylor	NREL

AUSTRALIA

DR HARRY SCHAAP, ELECTRICITY SUPPLY ASSOCIATION OF AUSTRALIA

Fig. 1 - One of Pacific Solar's Plug&Power rooftop installations. (photo courtesy of Pacific Solar)

GENERAL FRAMEWORK

The use of photovoltaic power systems (PV) in Australia has continued to increase, albeit with shifts in the performance of different market segments. Off-grid non-domestic applications still dominate Australia's cumulative installed capacity (about 58 % by 2001, down from about 75 % in the mid 1990's) but with a declining annual growth rate, now around 4 %. Off-grid domestic applications have enjoyed strong growth over the last decade and are now benefiting from the government support programmes aimed at increasing the use of BIPV and replacing diesel use with renewables. These applications accounted for 31 % of the cumulative installed capacity by 2001, up from 27 % the previous year.

Grid-connected installations continue to increase, now exceeding 10 % of the total installed capacity compared with less than 1 % four to five years ago. The national BIPV support programme (which commenced in 2000) and the renewable energy target for electricity retailers and major energy users (implemented in 2001) will assist in keeping this market segment growing strongly. The Australian electricity industry continues to play a role in both remote area power supply and grid-connected PV markets with interest being shown by both generating and retailing businesses, although the degree of interest varies between organizations. Interest has resulted from the industry being increasingly opened up to competition in a number of states (with contestability set to extend to residential customers in 2002), the operation of greenhouse gas reduction agreements or licence conditions and advancements in power conditioning and control system technologies, which have made the use of PV in hybrid systems more feasible.

The public continues to show an interest in and provide some support for the development and use of 'solar energy', for example through participation in Green Power schemes and installations on homes. However the relatively low energy prices, the lack of knowledge (and interest) amongst key parties in the energy market and the continuing high capital cost of PV have made it difficult for solar photovoltaic electricity to make a significant impact in Australia.

NATIONAL PROGRAMME

The Australian Government has initiated a number of measures to support renewable energy in general and, in some cases, PV in particular.

Mandatory renewable energy target – this target seeks to increase the contribution of renewable energy sources in Australia's electricity mix by 9 500 GWh per year by 2010. From 1 April 2001 electricity retailers and large energy users (known as liable parties) must purchase increasing amounts of electricity from renewable sources. A trade in Renewable Energy Certificates and financial penalties for non-compliance are features of this scheme.
Supporting the use of renewable energy for remote power generation (RRPGP) – this programme commenced in 2000 and will make 264 million Australian dollars available over four years for the conversion of remote area power supplies (including public generators and mini-grids) from diesel to renewable energy sources, and for new renewable installations that would otherwise have been fueled by diesel. The RRPGP may provide up to 50 % of the capital value of the replacement or new renewable generation for off-grid users of diesel-based power generation. This includes remote rural properties, communities and enterprises. A number of state governments also continue to provide financial support for off-grid renewables.

Supporting the use of solar photovoltaic electricity on residential and community buildings (PVRP) – this programme commenced on 1 January 2000 with 31 million Australian dollars available as rebates to householders or community building owners who install grid-connected or stand-alone photovoltaic power systems. Under the PVRP householders are eligible for a rebate of 5 AUD/W (minimum capacity of 450 W), capped at 7 500 AUD (or 1,5 kW). Extensions to an existing system can also attract a rebate. Community buildings attract the same rebate except it is capped at 10 000 AUD (or 2 kW). In the state of NSW the Sustainable Energy Development Authority boosts these householder rebates for new systems exceeding the cap, and provides support to other installations on buildings that may otherwise not be funded.

Supporting renewable energy commercialization activities (RECP) – This is a five-year 55,6 million Australian dollars competitive grants scheme.

The Renewable Energy Equity Fund has been established to provide venture capital for commercializing renewable energy technologies, and specific renewable energy projects are supported through the Renewable Energy Showcase Fund.

R&D, D

Commonwealth Government annual funding for PV R&D, D had increased to about 24,6 million Australian dollars by 2001 (compared to 5,6 million Australian dollars for the previous year), including the new market incentives. Funding from the state governments for the same period was around 1,9 million Australian dollars, slightly less than for the previous year.
Private sector funding was over 15 million Australian dollars for product development, demonstration and marketing. Industry funded

Fig. 2 - The first 100 square metres of solar panels manufactured by Sustainable Technologies International at the world's first Dye Sensitized Solar Cell manufacturing facility.
(photo courtesy of Sustainable Technologies International)

Fig. 3 - The first grid-connected PV system in the state of Tasmania attracted wide local media coverage that has raised awareness about PV and the potential for grid-connection of systems in that state.
(photo courtesy of Aurora Energy)

R&D, D remains focused on thin film PV, improvements in production processes, and development of concentrator systems. Joint industry and research institution activities continue in standards development and associated component testing. Grid-connected systems R&D is focusing on interconnection systems and building integration (particularly innovative mounting structures).

Australia now has a degree course specifically in PV Engineering at the University of NSW, as well as one in Renewable Energy Engineering at Murdoch University, which includes PV topics. Trade level courses are also being provided through the national Technical and Further Education sector. Short courses, diplomas and other post-graduate education are also offered, many of which are supported by the Australian Cooperative Research Centre for Renewable Energy. Students from around the world avail themselves of these courses.

IMPLEMENTATION

In 2001 the Australian Government offered funding through the RECP for a number of PV projects including first deployment of Pacific Solar's thin-film technology developed in Australia, a pilot plant to be established by energy retailer Origin Energy to commercialize low-cost PV cells and modules developed at the Australian National University, and a commercial solar concentrator system for both electricity and hot water developed by the Australian National University and Solahart Industries.

By late 2001, about 20 million Australian dollars had been committed under the PVRP, with most applications for off-grid systems and all states and territories being represented.

RRPGP sub-programmes have been approved in a number of states and territories, including South Australia, Queensland's Working Property Rebate Scheme, and the Northern Territory's Renewable Energy Rebate Programme.
Green Power sales from fifteen Green Power retailers rose to 470 GWh by mid 2001, an increase of 50 % from mid 2000. One third of the sales are from energy retailer EnergyAustralia's Pure Energy product. By mid 2001, about 60 000 consumers were signed up for some type of Green Power product (close to 1 % of residential customers nationwide). Although solar photovoltaic electricity represents a very small fraction of the total Green Power sold, the electricity businesses continued to install photovoltaic power systems throughout 2001. Currently 70 % of Green Power must be sourced from new generators, and this will rise to 80 % in 2002.

Throughout Australia interest in grid-connected PV continues to grow amongst electricity businesses, with some interest created by the need for renewable energy driven by Green Power schemes and some interest in response to customers' preferences. Although some utilities offer net metering, there is no uniform Australia wide approach. Some utilities still require detailed and complicated contracts, as well as interconnection requirements in addition to the Australian Standards.
In 2001 Australia's most southern utility, Aurora Energy in Tasmania, won an environmental excellence award for promotion of grid-connected PV through its net metering offer, simplified connection agreement, free of charge two-way electronic meter and waiver of application costs and other fees. A number of electricity businesses are also active in the RAPS market.

INDUSTRY STATUS

PV cell and module production levels fell slightly during 2000, reflecting a decrease of production capacity to 7 MWp due to the disruption caused by the merger and factory relocations of BP Solar and Solarex. This contributed to an increase in imports of cells and modules. However production of multi and single crystalline PV cells and modules from the new BP Solar plant will increase significantly, initially doubling to 15 MWp capacity and then increasing to 40 MWp in coming years.

A pilot production line for Sustainable Technologies International Titania dye sensitized solar cells began operation in 2001. Meanwhile, Pacific Solar has acquired another major shareholder Eurosolare and continues the development of its thin film polycrystalline silicon product, with pilot production underway and full-scale production scheduled for 2004.

There are several Australian manufacturers of inverters, typically supplying product in the range 500 W to 3 000 W for off-grid applications. Some are combined inverter/chargers, others offer energy management options. The grid-connected PV market is growing slowly and some manufacturers also provide grid interactive inverters. Pacific Solar has developed the world's first two-wire module inverter, which is being used in its Plug&Power' ac modules.

The current trend is to imported inverters. This appears to be for reasons of price as well as features available. The small Australian market has made it difficult for local manufacturers to compete with the rapid developments in the international marketplace. Several PV batteries have been manufactured in Australia, however, as with inverters, the trend is to imported products. In particular, there is a trend to the use of sealed batteries for health & safety reasons. This has been to the detriment of local manufacturers. Although not appearing in the Australian usage figures, there has also been an increase in imports of PV modules, which are subsequently re-exported in complete systems. Approximately 50 % of local module production is exported.

MARKET DEVELOPMENT

Growth in the local market accelerated slightly to 15 % (compared with 12 % the previous year) and a total installed capacity of 29 210 kWp was reached by the start of 2001.

Australia's vast size and sparse population have made effective remote area telecommunications, power supplies, water pumping, navigation aids and transport route signaling critical and expensive. PV continues to provide an important commercial alternative to diesel and central grid supplies for such applications. However, the telecommunications market has been disrupted by an outsourcing of off-grid power supply installations and maintenance and also by some saturation of that market sector.

While these non-domestic off-grid applications have traditionally been the major Australian market for PV, a large proportion (more than 80 %) of the new installed capacity (3 890 kWp) was on residential, commercial and educational buildings reflecting the impact of the Government rebate programme.

The built environment PV market is growing rapidly at present and continues to attract the interest of a variety of parties. Recent installations include roof-mounted systems on schools, commercial buildings and residences, systems integrated into structures such as lighting towers and ground-mounted systems of various capacities.

Fig. 4 - An 18 kW off-grid combined PV/wind power system installed at Inkerman Station on Cape York, Queensland. The system includes a 25 kW three phase inverter, a 1 400 Ah 120V DC battery bank and the existing 40 kVA generator has been incorporated into the system. The Inkerman RAPS system is a recipient of a rebate under the joint Australian and Queensland Governments' Working Property Rebate Scheme.
(photo courtesy of Ergon Energy)

FUTURE OUTLOOK

The near-term outlook for PV applications in Australia remains healthy with the continuation of the initiatives introduced for both off-grid and grid-connected applications by the Australian Government.
A number of state governments have developed energy policies that identify greenhouse gas reduction strategies as a priority. Also, local government greenhouse gas reduction initiatives are increasing and are resulting in greater knowledge about PV and its potential in the built environment.

Support for Green Power schemes continues to grow, however it still remains to be seen how these schemes will be impacted by the mandated requirement for electricity retailers to purchase renewable energy (which they can do at least cost).

Few PV installations to date have been for grid support or other distributed system benefits and it remains a challenge in Australia with its sparse population and extensive electricity distribution network to promote the real value of distributed generation sources such as PV through appropriate regulation and market mechanisms. Few investigations are underway into the use or value of PV for peak load reduction or grid support. In addition, access to the main electricity distribution networks continues to be difficult for small, distributed generation systems and procedures can be complex, non-uniform, slow and costly.

Further, some State electricity businesses apply additional charges, insurance and interconnection requirements, while some local governments require building development applications and fees for rooftop PV installations. Hence the installation of PV systems is still not a straightforward and accepted practice in Australia and considerable work is still needed to develop uniform installation guidelines, straightforward contracts and financial arrangements that would encourage PV use.

AUSTRIA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
DIPL.-ING. HUBERT FECHNER, ARSENAL RESEARCH

Fig. 1 - Hartberg Ecopark, Research Center, PV-modules as a shading element, Stadtwerke Hartberg. (municipal utility)

GENERAL FRAMEWORK

At the Kyoto conference, Austria committed to reduce 13% of its own Green House Gas emissions from today's 7.6 tons/capita per year towards around 6.6 tons/capita per year in 2010. The Ratification of the Kyoto Protocol, as well as the acceptation of reduction measures and evaluation procedures are in discussion within the Austrian government and haven't been decided on as of yet.

2001 was one of the most important years with regard to the electricity market in Austria. Based on the principles of the Electricity Law, so called EIWOG 2, the electricity market has been 100% liberalized since 1 October 2001. By fully liberalizing the electricity industry, electricity becomes an article of merchandise. The whole process and the market rules are observed by a new independent regulatory body, the Electricity Control Commission. The following objectives shall be reached through the Electricity Law EIWOG 2:

1. Free customer choice - Customers can choose freely from whom to purchase electricity. The prices of electricity are significantly decreased due to the access of all consumers to the open European electricity market. This significant decrease of electricity prices might be contra-productive to PV market penetration due to the higher costs in comparison with competitive technologies.

2. RES target quotas - The most important parts with regard to market penetration of new renewable energies such as PV, biomass, wind power etc. are the energy political target quotas rising from 1 % in 2001 up to 4% in 2007 in two year steps. Here's a view of the actual electricity market: About 70% of approximately 60 TWh annual electricity consumption is generated by renewable energy sources, almost exclusively from hydro power. This is the highest figure of all European Union member states and mainly caused by Austria's topographic situation and the historical development of the electricity market. To promote the extension of new RES, legislators of EIWOG 2 fixed the above mentioned target quotas. The share of, at a minimum of 1% or about 600 GWh, couldn't be reached as of October 1, 2001. The missing share of about 0.4% new plants shall be financially supported via funds which are paid through penalties of network operators with quotas less than the legislative targets.

3. Disclosure of primary energy shares - The law states that consumers' invoices must describe the portions of primary energy sources from which the delivered electricity has been generated. Traders and suppliers are obliged to ensure that this information is in place. The first disclosure appeared at the end of October 2001. The verification system is settlement based and the rules are as follows: i) certificates of origin issued by recognized and chartered certification organizations are accepted, ii) statements concerning the origin of primary energy, officially published in annual business

reports and approved by the chartered auditor are accepted and iii) if neither of the above are available then the UCTE-mix applies.

4. Standardized energy supply patterns - Network operators manage the continuous availability of electricity by using standardized energy supply patterns of small and middle sized systems. Most grid-connected PV systems and small hybrid systems match this low power segment with less than 50kW connected load and less than 100 000 kWh/a. The reason for accepting standardized energy patterns lies in the legislative framework for guaranteeing the grid access of Renewables without any discrimination.

NATIONAL PROGRAMME

The principles of ElWOG 2 are going into force via federal decrees in each of the nine regions. The federal governments determine the different types of promotion strategies by designing the financial incentives and allowing voluntary approaches like e.g. Green Tariffs. Two general types of financial incentives are used: i) The feed-in tariffs paying the supplied solar electricity per kWh and ii) the investigation support paying the subsidy per kWp capacity. The feed-in tariffs of grid-connected PV systems (GCS) vary between 10 and 74 EURcent/kWh, depending on the region, on the system size as well as on seasonal and day/night aspects. The investigation support is foreseen for small GCS and is limited up to 4 000 EUR per kWp. As a result of the higher feed-in tariffs, the extra costs for the network operators will be compensated by an additional supplement on the customer invoices.

Newcomers to the electricity markets are offering their green products directly to customers. Green electricity is a general tradable good like, e.g., biological food. An increasingly popular mechanism to promote the market introduction of Renewable Systems is Ecolabels. Ecolabels are voluntary instruments based on econonic-political grounds for transferring ecological values of generation processes. The aim of such labelling is to enhance market transparency and allow customers to make informed choices among different products and suppliers by guaranteeing the origin of supplied green electricity. Within the certification procedures, certain criteria are checked through independent certification institutes. One criteria which has to be fulfilled for getting the Austrian Ecolabel "Umweltzeichen", is to verify the share of at a minimum of 1% PV within the portfolio of the labelled green electricity. The positive image of solar electricity in the minds of customers led to this jointly defined requirement. So far, only young players on the electricity market have received the Austrian Ecolabel "Umweltzeichen."

RESEARCH, DEVELOPMENT AND DEMONSTRATION

Since the end of the Austrian 200kWp Rooftop Programme in 1999, the Austrian PV research activities are now focused on project base. The involved research organizations and companies are participating in various National and European projects as well as in different tasks of the IEA-PVPS Programme. The RTD development and

Fig. 2 - Futuristic "Gemini Sun House" at the Styrian state exhibition "Energy" in Weiz, 3 different PV-systems, partly with tracking, 6.7 kWp, AEE.

approach is widespread located and decentralized oriented. Some principal descriptions of these projects may highlight the general RTD trend of Photovoltaics in Austria:

New solutions for building integration of PV are investigated to reduce the costs and address the building industry by aiming to create a better understanding about possibilities and challenges of high integrated concepts for roofs, facades and other building elements. Another key activity within the solar architecture trend is the construction of so-called "Energy Plus" houses. These futuristic houses are producing more solar electricity from their own BIPV than they consume themselves. To meet various aesthetic demands, artistic contact patterns are designed and optimized on multi-crystalline silicon solar cells.

The stricter the acoustic principles the greater the demand for sound barriers. Higher feed-in tariffs, reduced costs and the synergetic use of obstructed highways lead towards the extended installations of PV sound barriers. The costs of the grid connection are rather low, because the requests for installing sound barriers are coming from citizens in the neighbourhood of the highways, and they need the electricity in their households.

Organic solar cells based on thin plastic films developed at the University of Linz (Upper Austria) have received increased attention due to their unique properties. These cell types promise more than likely to become the cheapest solar cells of the future. A maximum efficiency of about 2,5% has been achieved through bulk hetero-junction cells.

Fig. 3 - Energypark West in Satteins, 220 m² energy-facade with PV & thermal modules, 17.16 kWp, stromaufwaerts GmbH.

IMPLEMENTATION & MARKET DEVELOPMENT

Roughly 6,5 MW of PV power had been installed in Austria by the end of 2001. Between 1995 and 2001, the growth of the total capacity accounted for a mean annual of 30%. Until the end of 1996, the off-grid sector dominated the Austrian PV market. However, from 1997, the majority of new systems were grid-connected according to the overall trend in the IEA PVPS reporting countries.

As in most other countries, off-grid installations were the first economic alternative for PV systems. Small autarkic systems provide electricity to technical systems, or for domestic use in alpine households or mountain huts, far away from the grid. However, this is not exclusive to remote areas, but PV application to urban sites is an increasing option to supply infrastructure systems like parking meters or rail-greasing systems.

With improved integration into the built environment on-grid distributed systems are becoming more and more common place in the public interest. More than two-thirds of the overall installed capacity are grid-connected systems in Austria.
Due to limited space available, grid-connected centralised systems play a minor role and so far, only 140 kW are installed.

INDUSTRY STATUS

There is no PV cell production in Austria for the moment but several companies are producing components for PV systems:

ISOVOLTA is manufacturing coloured back sheet laminates for PV modules for almost all module manufacturers in the world.

FRONIUS has been engaged in solar-electronics and is now Europe's second largest producer of inverters for grid connected and stand alone PV systems. So far, more than 5 000 units have been produced; out of which 90% were exported into other countries.
Banner Batterien, like Isovolta and Fronius, are important manufacturers of lead-acid batteries for off-grid PV applications.

FUTURE OUTLOOK

The reached position of PV research and development has to be continuously improved to follow the dynamic know-how and learning process of the world-wide PV development progress. Training and education demands will emerge automatically with the increasing number of PV applications. The more industry and research organizations contribute to the application of PV, the more automatically aspects of vocational schools and universities will be supported. It is urgently necessary to develop up-to-date tutorials for growing interest groups in Austria.

Financial incentives and voluntary approaches are the basis for a stronger PV market in Austria. Some new regulations in Austria could yield a substantial effect for a lasting development towards a powerful dissemination of PV, even though only in some parts of the country.

CANADA

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
DR. LISA DIGNARD-BAILEY, CANMET ENERGY DIVERSIFICATION RESEARCH LABORATORY (CEDRL), NATURAL RESOURCES CANADA

GENERAL FRAMEWORK

Three specific issues on Canada's energy scene are favouring the increased use of solar photovoltaics: first, international commitments to Green House Gas emissions reductions and climate change mitigation given their far-reaching implications for energy and the environment; second, the deregulation and the restructuring of the electricity industry that is leading to an increased acceptance for distributed and on-site micropower generation; third, the coming change in global energy markets in which photovoltaics is among the fastest growing forms of energy and the business opportunities this presents to Canadian industry.

The Government of Canada supported several new initiatives within the Climate Change Action Plan 2000[1]. Several federal departments have collaborated with the Photovoltaic (PV) industry and regional partners to deliver projects within the Technology Early Action Measures Program, the MicroPower-Connect initiative[2], and the expansion of the REDI program for On-site generation at Federal facilities. Together these projects are helping to raise the awareness of this emerging technology, as well as contributing to their improvement and cost reduction targets.

Despite the relatively low price of conventional energy, many Canadians are contributing to the growth of the PV market and industry. A sustainable market for remote and off-grid applications has developed over the last 10 years in Canada. This market continued to show strong growth with an average of 25% per year (Table 1). The installed power capacity was 7.15 MW in 2000 and is expected to exceed 8.5MW in 2001. This is an unsubsidised market that is growing because PV technology is meeting the remote power needs of Canadian customers particularly for transport route signalling, navigational aids, remote homes, telecommunication, and remote sensing and monitoring.

TABLE 1: CUMULATIVE PV POWER CAPACITY INSTALLED IN CANADA

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
PV power (MW)	0.96	1.24	1.51	1.86	2.56	3.38	4.47	5.83	7.15

The public perception of solar energy is very positive and in 2001 a growing number of Canadians demonstrated their environmental commitment by installing grid-connected PV on their residence, commerce or industry. A concerted effort is now required to remove market barriers and encourage the development of the grid-connected market segment in Canada. Networks between architectural firms, building engineers, electricians, and the PV industry need to be fostered. This is one of the conclusions of a new report released by CANMET-EDRL entitled "Photovoltaic for Buildings – Opportunities for Canada[5]". Already leading architecture and engineering firms with expertise in Green-Building design are demonstrating their interest to propose PV-building products to their clients. This has led to the installation of several new Photovoltaic-building installations in Canada in 2001 (Figure 1).

Fig. 1 - The renovation of the Richard Blanchard building for the Ministry of Health in Victoria, British Columbia incorporated Building-Integrated PV elements to replace the opaque spandrel panels on a section of the façade. This 2.6kW demonstration was championed by the BC Green Building Program and the BC Building Corporation. (photo Gordon Howell)

NATIONAL PROGRAM

The federal Department of Natural Resources (NRCan) is responsible for energy policies and energy R&D in Canada. Within the framework of the Renewable Energy Strategy, NRCan's CANMET Energy Diversification Research Laboratory (CEDRL) is responsible for the management of the federal photovoltaic R&D and technology transfer program. This includes technical support for research on components and systems in collaborations with industry and major end-users, as well as the development of standards and codes. This photovoltaic R&D program is financed by the federal fund allocation by the Program on Energy Research and Development (PERD). In addition, the Renewable Energy and Electric Division (REED) is responsible for policy support and is actively supporting PV training and marketing activities to promote the use of photovoltaic and other renewable energy technologies in Canada

The strategies of the Canadian R&D photovoltaic program are:

- To conduct R&D that will contribute to the improved performance of PV system components and applications in cold climates;
- Provide leadership and technical support that will foster the market deployment of PV technology by removing technical and non technical barriers;
- Collaborate with key partners and stakeholders to increase the awareness of the potential and value of PV;
- Provide support to globally competitive PV manufacturers that can significantly contribute to Canada's Climate Change objectives.

R&D PROGRAM

The Canadian R&D program supports the development of technologies, the evaluation of the performance of PV systems in new applications and their adaptation for use in cold climate conditions.

This work is conducted in collaboration with the industry at the CANMET-Energy Diversification Research Laboratory, a National research facility located near Montréal in the Province of Québec. Current projects include:

- A comprehensive research program to evaluate the use of small PV-hybrid systems in order to optimise their performance and reduce their life-cycle cost[6];
- Evaluating the energy performance of commercial PV modules operating in Canadian climatic conditions and contributing to the development of international PV module standards;
- Assessing the performance of PV products designed for building integration, including participation in an Internal Energy Agency task group that focuses on PV in the built environment;
- Conducting research to improve the efficiency and performance of inverters and balance of systems components used for utility interconnected PV systems;
- Championing the development of a national guideline for the interconnection of small distributed generation systems, including PV, wind, microturbines, and fuel cells, in collaboration with the Electrofederation of Canada;
- Supporting the development and adoption of performance and safety standards for use in Canada, including participation in the International Electrotechnical Commission working groups that aim to develop international standards.

Fig. 2 - This residence is powered by a PV/Genset hybrid system in Whitehorse, Yukon, and is being monitored as part of the Canadian PV-Hybrid R&D Program at CANMET-EDRL.

CANMET-EDRL also developed a Project Analysis Software Tool, known as RETScreen that can be downloaded from the web free-of-charge[7]. First released in 1998 for on-grid applications, the RETScreen 2000 model was upgraded to cover off-grid PV applications, including stand-alone, hybrid and water pumping systems. Training modules presenting case studies were completed to provide guidance to those interested in assessing the cost and benefits of PV systems in various applications in 2001.

DEMONSTRATION PROJECTS

BC Ministry of Health BIPV Facade

The British Columbia Ministry of Health was refurbishing the façade of the Richard Blanchard building in Victoria. As part of the Green building program initiative, building-integrated Photovoltaic (BIPV) panels were selected to replace the traditional spandrel panels above the entranceway of the four-storey building. The 2.66 kW system designed by BCIT, incorporated twenty PV panels manufactured by Saint-Gobain using Photowatt solar cells (Shown in Figure 1).

Niigon manufacturing Facility 42kW PV system

The Moose Deer Point First Nation Band, Husky Injection Molding Co. and the Schad Foundation collaborated to build a new manufacturing facility as part of a new sustainable community development. The 42 kW PV rooftop array installed by ENERMODAL on the Niigon Technologies Ltd injection molding facility was funded because of its environmental benefits. The new manufacturing plant located on the shore of Georgian Bay, Ontario was designed to meet the National Model Building Code and reflects the social and environmental commitment of this First Nation community.

Saskatchewan Science Centre

A 2.8 kW PV rooftop array has been installed by SOLTEK above the entrance of the Saskatchewan Science Centre in Regina. The City of Regina was the site of the annual Solar Energy Society of Canada Conference – Solar Odyssey on September 28-30, 2001. The provincial electricity company, SaskPower, supported this installation and the educational exhibits at the Science Centre as part of the educational component of their Climate Change Action Plan (Figure 3).

Toronto CN Tower

Automation Tooling Systems, SolSource Engineering and the CN Tower management collaborated to install a PV array at a height of 400 meter on the south face of the Tower. This 1kW grid-connected system has an educational display to inform visitors on the benefits a solar energy. Their aim is to install a façade with a power capacity of 140kW once the initial testing phase of this project is completed.

OPG Evergreen Energy PV rooftop array

A 4.8 kW system was commissioned at Evergreen Energy, an operating unit of Ontario Power Generation in 2001. With the deregulation of the electricity market in Ontario, Ontario Power Generation aims to provide customers with Green power purchasing options. This PV system designed by SolSource Engineering and ARISE is part of a growing renewable energy portfolio of projects that Evergreen Energy will develop.

Fig. 3 - An interactive exhibit was installed at the Saskatchewan Science Centre to demonstrate that Photovoltaic panels can provide clean electricity to homes in Canada. (Demonstration by Rob Dumont of Sask. Research Council during the Solar Energy Society of Canada annual conference. (photo Gordon Howell)

IMPLEMENTATION

Canada is developing a National Implementation Strategy in order to reduce its greenhouse gas emission by 6% from 1990 level. In 2000, the federal government committed an additional $500million to accelerate progress towards the reduction of Greenhouse gas emissions. There has also been a commitment to provide investments in technologies that will have impacts in the post 2010 period. Within this framework, several climate change measures have been initiated that should benefit the PV industry and other stakeholders:

- Technology Early Action Measure Program - This is a cost-shared program for the development of innovative technologies and their demonstration in the market place. Several PV technology proposals were approved under this program;
- MicroPower-Connect Initiative - This is an initiative that aims to develop and harmonise the requirements for the interconnection of emerging technologies, such as PV, wind, fuel cells, and microturbines;
- On site Generation at Government Facilities - As part of its climate change action plan, the government of Canada will support the installation of approximately 15 PV systems over the next three years. Preference will be given to high visibility projects that demonstrate the application of Building-integrated PV products;
- Climate Change Technology and Innovation Program - As part of this measure, the National Science and Engineering Research Council will manage a research fund for novel next-generation energy technologies related to greenhouse gas mitigation. This program targets early-stage and exploratory research in Canadian Universities and will enhance the knowledge base for longer-term solutions to climate change[10];
- Federation of Canadian Municipality (FCM) Green Fund - The federal government provides funding to the FCM to initiate green energy projects. By partnering with a local community champion, PV companies have an opportunity to propose PV deployment projects.

The restructuring of the electricity market in North America is drawing more interest in providing customers a power choice. Much of the regulation for electricity in Canada is under provincial jurisdiction. Alberta was the first Province to deregulate the electricity industry and electricity is traded on the Alberta Power Pool since January 1996. In May 2002, the Province of Ontario will also deregulated their electricity industry sector. Ontario Power Generation has created the Evergreen Energy division to offer Green power to their customers. In 2001, Evergreen Energy installed a 4.8kW PV power system on their rooftop, as part of their renewable energy portfolio. Several major utility companies, such as Enmax in Alberta, now offer green power (mainly wind power) for a premium to their customer base. There is no provincial legislation mandating net-metering options be provided to customers in Canada. Small systems installed by residential customers can, in principal, be approved on a case-by-case basis for interconnection; however, the process is still costly and lengthy. SaskPower is the only provincial electricity company that has an incentive program that targets farmers who wish to purchase small PV or wind powered water-pumping systems.

INDUSTRY STATUS

The Canadian PV industry has grown steadily serving both its domestic off-grid market and the export market. There are approximately 150 organisations actively promoting PV power. These are mostly system suppliers and installers but approximately 15 companies are involved in manufacturing. Many of them are members of the Canadian Solar Industries Association or Énergie Solaire Québec[12].

Automated Tooling Systems (ATS), based in Cambridge Ontario is a North American leader in automated manufacturing and test systems, and a large volume producer of precision components. It has developed automated manufacturing equipment for manufacture of solar cells and modules. In 1997 it acquired its subsidiary, Photowatt International S.A, that has grown into one of the world's largest solar module manufacturers. In 2001, its PV division continued its research and development effort for a next-generation, flexible and lightweight technology, known as Spheral Solar™. It also expanded its PV rural electrification activities in Western China.

Xantrex Technology Inc. based in Vancouver, British Columbia, Canada has acquired and formed an alliance with Statpower, Heart interface, Cruising Equipment and Trace to create the world's leading supplier of advanced power electronics. The company is positioned to serve a growing photovoltaic market worldwide, and has products ranging from DC/AC inverters, battery chargers, and grid-interactive power conditioners that targets mobile, recreational, industrial and distributed power applications.

ICP Global Technologies, a leading supplier of consumer products in North America, has expanded its operations to manufacture a new line of PV panels. Its new manufacturing facility in Montréal, Québec was inaugurated in October 2000. ICP Global won a design

and engineering award for its iSun Power Charger at the Consumer Electronics Show.

A network of systems integration companies has established distribution and dealer networks that effectively serves a growing Canadian PV market. These include distributors for Siemens Solar, BP Solar (Solarex), Kyocera, Photowatt and UniSolar. These module manufacturers offer PV module product warranties ranging from 10 to 25 years and have certified their products to international standards.

MARKET

The Canadian PV installed capacity is now 7.15 Megawatt with a sustained domestic market growth that has averaged 25% over the last eight years. In 2000, the annual PV module market stabilised at around 1.3 Megawatt per year. There was a surge in commercial and industrial applications in 2000 with 70% (928kW) of the sales going to this off-grid application sector. Most of the remaining PV power sales were for off-grid residences and other recreational applications (382kW). It is estimated that the Canadian PV industry generated revenues of 42 million CAD and employed approximately 260 people in 2000.

There are still many barriers to the development of the grid-connected market sector in Canada. In particular, residential customers find the installation and approval process costly and lengthy. Commercial and industrial customers generally have dedicated staff and expertise to deal with the various steps and are more likely to pursue projects. It is estimated that there were approximately 10 grid-connected installations in Canada in 2001 representing a total power capacity of around 60kW - this is a significant increase compared to the 18kW reported in 2000.

FUTURE OUTLOOK

PV power systems have demonstrated that they are a reliable source of electricity and the public perception of this technology is favourable. Nevertheless, increased knowledge of this energy choice is required to maintain the growth of its domestic market. NRCan continues to support several promotional and marketing activities in collaboration with the Canadian Solar Industries Association and Énergie Solaire Québec. It has initiated a collaboration with Parks Canada to increase the impact of its outreach activities that will contribute to promoting clean energy sources and educate the general population.

A concerted effort is now required to encourage the development of the grid-connected market sector in Canada. CANMET-EDRL recently completed a study examining the benefits of on-site generation using photovoltaic technologies on buildings in Canada. Several new activities have been initiated as part of an action plan that aims to build on Canadian Industry experience base and address some of the market place barriers that currently exist. New government investments in R&D for Building-Integrated PV technology, support for the development of a technical guideline for the interconnection of small power supplies, and support for demonstrations of PV on building in high-visibility sites throughout Canada will contribute to facilitating the market introduction of PV technology for grid-tied applications in the medium to long term.

Footnotes with relevant web sites:

[1] *Climate change web site: www.climatechange.gc.ca*

[2] *Removing barriers to interconnection: www.micropower-connect.org*

[4] *Renewable Energy and Electricity Division: http://nrcan.gc.ca/es/reed CANMET-EDRL conducts an annual market survey to follow the progress of the PV market in Canada and collaborates with the International Energy Agency to produce an annual survey report, refer to: www.iea-pvps.org*

[5] *Photovoltaic for Building report: http://cedrl.mets.nrcan.gc.ca/*

[6] *PV-Hybrid Program newsletter: http//cedrl.mets.nrcan.gc.ca/*

[7] *Free software tool: http://www.retscreen.gc.ca*

[8] *OPG green power: http://www.opg.com/envcomm/E_greenPower.asp*

[9] *REDI ON-SITE initiative: http://nrcan.gc.ca/es/erb/reed*

[10] *Funding University research: http://nserc.ca/guide/ghgm_e.htm*

[11] *Green Municipal Fund: www.fcm.ca*

[12] *Directory of members and companies available from: the Canadian Solar Industry Association www.cansia.ca; and Énergie Solaire Québec www.esq.qc.ca*

DENMARK

PV TECHNOLOGY STATUS AND PROSPECTS
FLEMMING KRISTENSEN, ENERGIMIDT, DENMARK
PETER AHM, PA-ENERGY A/S, DENMAR

Fig.1 - 4 kWp system from Sol 300 (village)

GENERAL FRAMEWORK

Renewable energy technologies are a high priority in the national Danish energy plan, Energy 21. The goal is partly to reduce the emission of CO2 by 20 % before year 2005 and partly to diversify the energy sector now being based on fossil fuels. At present, about 10 % of the gross national energy consumption originates from renewable energy sources. Energy 21 outlines scenarios, where i. a., photovoltaics (PV) may contribute to about 7-10 % of the national electricity consumption of Denmark in year 2030. However, no specific goals for PV deployment have yet been set, but this can be expected to change in the near future, as public perception of building integrated PVs constantly increases.

NATIONAL PROGRAMME

PVs have been included in the action plan of the Danish Energy Agency (DEA) since 1992 and have received increasing attention in the consecutive three-year Solar Energy Action Plans. Since 1992, the Renewable Energy Development Programme of the EA has supported about 120 PV projects, and by the end of 2001 about 1.5 MWp had been or were being installed in the context of demonstrations plants. A 300 rooftop's project including 750 kWp was launched early 1998 and was completed by end of 2001.
A 1 000 roof-top programme has been launched late 2001 as a follow up; this programme targets a mix of general cost reductions, increase in end-user payment and promotion of small roof-tops. Only a few weeks after the announcement of the project, the SOL 1 000 project, more than 3 000 house owners had registered their interest.

A special support programme for PV applications in the commercial sector, funded by the CO2 tax on electricity, was set up early 1998. The support includes a subsidy of up to 40 % for the turnkey costs. The calculation of the actual subsidy will be in favour of high yield installations. This programme has so far not been very successful, as the commercial sector seems to regard an incentive of 40 % as inadequate, and during 2001 only very few projects have been implemented using this support mechanism.

Net metering for privately owned PV systems was established mid-1998 and at that time for a pilot-period of four years. Work is ongoing to make this system more permanent. A small project has been launched to identify the best possible institutional arrangements around PV systems on multi-family buildings and housing.

In late 1999, the parliament allocated 30 mio DKK for a new three-year programme, 2000 – 2002, to promote building integrated PVs in apartment buildings and institutions. The programme includes both development of new integration methods, new components and demonstrations. A small PV cell R&D activity is included as a well targeting PEC technology. At the end of 2001, four calls for proposals had been carried out in this programme resulting in 52 proposals of which 23 have received support corresponding to about 14 mio DKK. The programme has created interest for PVs in Danish building industry.

Efforts to establish a unified PV programme as a replacement for the so far fragmented approach with separate, consecutive narrow-focused programmes have been started, but no immediate results are expected.

RESEARCH & DEVELOPMENT

R&D on PV cell manufacturing (mono-X Si) has taken place at the Technical University of Denmark for more than a decade. This R&D effort led to the establishment of the first Danish PV cell/module manufacturer in 1992. The company folded mid-1996 after a period in receivership, and has now been reconstructed as a module assembling plant. Research into Si cell production with focus on surface layer structure and contacts at the Danish Institute of Microelectronics has been stopped. However, as part of the new 3-year programme mentioned above, R&D activities into PEC cells (Grätzel type cells) has been initiated at the Danish Institute of Technology. This initiative received additional support from the Public Service Obligation (PSO) of the Transmission Systems Operator (Eltra) in 2001.

In mid-1995, the Photovoltaic System Laboratory (PVSyslab) was established in collaboration between Risoe National Laboratory and the Danish Institute of Technology. The main function of PVSyslab is to certify the quality of PV systems and to help industry develop better products, systems and recommended practices for design and installations. The PVSyslab has established R&D PV plants and has put examples of building integrated PV technology on display. The PVSyslab has established a national database for demonstration systems and operational data from these systems are published regularly. The PVSyslab, which is now integrated into the Solar Energy Centre Denmark, is active as the group leader in the CENELEC & IEC TC 82 work and participates in the GAP initiative. The Solar Energy Centre Denmark has recently entered the field of technology cooperation with developing countries and is presently engaged in Nepal and Malawi.
Inverter technologies are being R&D'd for both fuel cell and PV applications. Efficiencies of up to 98 % have been reported using transformer-less, high integrated designs, and efforts to develop smaller units, about 2 kW and smaller, are ongoing.

Stimulated by the above mentioned three-year programme 2000-2002, which supports up to 40% of R&D costs, the Danish building industry has exhibited increasing interest in the integration of PV's in existing and new building components, and a few new products have emerged.

IMPLEMENTATION

The potential for wide deployment of PVs in Denmark has been identified as building integrated systems.

Several grid-connected, building integrated PV systems were commissioned in 2001, including some of the last installations in the Sol-300 project. (See Fig. 1 and Fig. 2).

Both the Sol-300 and the SOL 1 000 projects intend to demonstrate highly visible and architectural acceptable integration of PV technology on existing single family houses, to reduce costs and to increase end-user payment; thus preparing the introduction of a standard subsidy for PVs initially of about 35%. A secondary objective has been to disseminate information and experience on PV rooftop deployment to the Danish distribution utilities.

Several projects for building integrated PV systems including commercial buildings, apartment buildings and schools have been implemented, typically in the range of 2-15 kWp.

Fig. 2 - 2,55 kWp system from the Danish BIPV programme.

Fig. 3 - 4 kWp system from Sol 300. (village)

INDUSTRY STATUS

PV cell production stopped in Denmark in 1996. A single Danish module manufacturer (Gaia Solar) with an annual capacity of about 1 MWp per shift has existed since 1996. A few other companies producing tailor-made modules such as window-integrated PV cells can be found.

Some medium to large-scale industrial corporations long established in the building industry, such as Velux Industries and Dansk Eternit, continue and increase their R&D into how to integrate PVs in their mainstream products. The products are currently under field tests in the context of demonstration projects. New companies are also exhibiting interest in this field.

There is no PV relevant battery manufacturing in Denmark at present.

A few companies develop and produce power electronics for PVs, mainly for stand-alone systems for the remote-professional market sector.

A number of companies are acting as PV system houses, designing and supplying PV systems to the already competitive international market sector of remote stand-alone applications.

Consultant engineering companies specializing in PV application in developing countries report a slowly growing business area.

Total PV business volume was estimated to be about USD 15 mio in 2001; a reduction compared to 2000, mainly because of the Sol-300 project having finished and the SOL 1000 project having just stated up ultimo 2001.

Fig.4 - 3,9 kWp system (thin film) from the Danish BIPV programme. (old warehouse)

MARKET DEVELOPMENT

Market development incentives already in place are mentioned above under the National Programme. A standard incentive for privately owned rooftops are not yet in place, but a subsidy for PVs on apartment houses is part of the new three-year programme. Utility PSO (Public Service Obligation) support for PVs was first used in the Sol-300 project. The frame for PSO funding for PVs was about in 15 mio DKK in 2001.

The cumulative installed PV capacity in Denmark (including Greenland) by end of 2001, was estimated to be about 1.5 MWp.

FUTURE OUTLOOK

The new SOL 1000 project and the ongoing three-year programme targeting building integrated PVs on single-family houses, respectively apartment houses and institutions, are expected to lead to the future availability of increasing Government funds for PVs.

However, a constant development towards commercial sustainability for PVs is seen as critical for continued support from the Government and the utilities. Danish efforts to promote PVs have so far been rather fragmented, and there is now a growing understanding of the need to establish a more concerted effort in order to underpin and consolidate the growing but still very weak commercial PV sector.

FINLAND

PV TECHNOLOGY STATUS AND PROSPECTS LEENA GRANDELL, MOTIVA OY

GENERAL FRAMEWORK

During the past decade, the main emphasis on the promotion of photovoltaics in Finland has been on research and development. However, this changed when the Ministry of Trade and Industry launched an Action Plan for Renewable Energy Sources in 1999 in which more emphasis was placed on the enhancement of domestic market development. The Action Plan is one crucial part of the National Climate Strategy, which has been formulated to achieve the goals of greenhouse gas reductions set for Finland by the Kyoto Protocol.

The main actors in the photovoltaic sector in Finland are comprised of several companies, both supplier and consultant companies, a number of research institutes, and two associations. Within the government, the Ministry of Trade and Industry has the main responsibility for enhancing renewable energy sources, including photovoltaics, but also the Ministry of Environment acts in the housing sector. Motiva, the Energy Information Centre for Energy Efficiency and Renewable Energy Sources has also an active role in the enhancement of the market.
One of the key disincentives to growth in the PV markets is lack of proper information. A fundamental belief is that the northern climate would form a severe hindrance to the utilization of solar energy. However, the growing number of demonstrations sites, as well as the fairly widespread use of photovoltaics on summer cottages has slowly overcome these attitudes.

NATIONAL PROGRAMME

The Action Plan for Renewable Energy Sources sets objectives for the volume of energy generated by renewable sources in 2010, and in addition, a prognosis on the development until 2025 is included. The relative increase of photovoltaic markets sought until 2010 is significant even though its absolute volume is still modest.

The ambitious goal set by the Action Plan for Renewable Energy until 2010 is to increase the production by 50%, when compared to production in 1995. A further goal is to double the use of renewable energy sources by the year 2025. This increase is, to a large degree, foreseen to rely on bioenergy and hydropower, but ambitious goals have been set for photovoltaics as well. The objective for installed photovoltaic capacity in 2010 is 40 MWp, meaning a 20 fold increase when compared with the 1998 situation.
The prognosis for 2025 is 500 MWp. Thus, the main emphasis in the coming decade is in creating the needed infrastructure (awareness, information dissemination, export, industrial activities) whereas volume effects are sought later. The impact of photovoltaics on the total environmental effects of the Action Plan is assessed to be less than 1% for 2010.
Following the launch of the Action Plan, a thorough investigation of the concrete steps and actions in order to reach the ambitious goals set for photovoltaics has been conducted. The main emphasis is placed on photovoltaics in buildings, but also on stand-alone systems. Applications for developing countries are included.

RESEARCH AND DEVELOPMENT

Research and development work on photovoltaics is carried out by a number of institutes, mainly Helsinki University of Technology, Tampere University of Technology and Technical Research Centre of Finland. Also several companies, such as Naps Ltd and Rautaruukki Oy, are active in the field.

The "Photovoltaics in Finland" programme managed by Tekes, Technology Development Centre, focused on industrial solar cell production with the intention to provide technological requisites for inducing industrial production. Both research institutes as well as industry participated in the programme. The main emphasis was on solar cells based on crystalline silicon. The program ended in 2000. Since then, public research funds are being dealt on by project basis. During 2001, a couple of research institutes and companies received funding mainly for development of individual components as well as optimisation on the system level.

Helsinki University of Technology, being the main actor in the research field, concentrates on system development, research on ageing phenomenon of solar cells as well as new materials.

INITIATIVES FROM GOVERNMENT AND UTILITIES

"Green electricity" has been introduced to the electricity markets and utilities are increasingly interested in demonstrating building integrated PV systems as part of their environmentally friendly image. This has stimulated private consumer interest to PV power as well. Preliminary interest has also been shown for an ESCO type financing approach for PV installations.

Fig. 1 - Villa 2000, building integrated PV elements (2.4 kWp) by Rautaruukki Oy.

Fig. 2 - Helsinki University of Technology, Department of Electrical Engineering. Solar panels mounted on shading elements forming a total of 60 m2 panel area and 7 kWp peak power.

Until the end of 2001, investment subsidies (up to 30%) have been only available to communities, organizations and enterprises. However, this will presumably change during 2002. The subsidy level will rise up to 40%; which will be comparable to wind energy investments in Finland. Another change sought in the near future is that subsidies will be made available to private persons. This will very likely in the first state comprise only new buildings, but later, investments made at renovation sites, as well.

INDUSTRY STATUS

The main industrial player is Naps Ltd with its business unit Naps Systems Oy. Naps markets different PV applications and its market share in Europe is approximately 10%. About 10 companies are active on the system level.

One new product launched in the market in 2001 was the roof top integration of 64 Wp and 128 Wp PV modules by Rautaruukki Oy. The product was demonstrated in 2000 at the Tuusula housing exhibition and is based on an innovation dealing with the integration of the modules with the remaining roof structures.

MARKET DEVELOPMENT

Photovoltaic markets in Finland can be divided into three main segments:

- Built environment
- Summer cottages, recreational boats and other applications with electricity consumption concentrating on summer months
- Larger applications in remote areas (>1 kWp)

The domestic markets are still dominated by small solar home systems for vacation houses, typically 50-100 Wp in size. The estimated potential is some 120 000 units due to the high number of summer cottages. Examples of larger applications in remote areas are telecommunication base stations or weather stations. Also, the Finnish Coast Guard operates some 20 larger stand-alone hybrid systems. During recent years, building integrated applications have formed a new important market segment. A number of PV systems in the built environment exist, the largest of them being a 39 kWp system mounted on the roof top of a supermarket in Lielahti, Tampere. A new larger scale system is planned to be mounted at Ekoviikki, an environmentally friendly housing area with emphasis on solar energy utilization.

FINNISH PV SYSTEMS 2001

	Power (kWp)
Solar home systems	2 392
Stand-alone systems	249
Grid-connected (utility)	30
Grid-connected (roof-top)	77
TOTAL	2 748

(the cumulative installed capacity)

Expected Developments

The photovoltaic markets in Finland will continue to concentrate on small scale consumer applications but building integrated systems are becoming a new important market segment. The subsidy level will rise from the present 30% to 40% in 2002 and subsidies will very likely be made available to private persons. During the coming years the enhancement of photovoltaics markets will emphasise creating the needed infrastructure including information activities, education, and industrial activities.

FRANCE

PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS IN FRANCE

ANDRÉ CLAVERIE
FRENCH AGENCY FOR ENVIRONMENT AND ENERGY MANAGEMENT (ADEME)

GENERAL FRAMEWORK

In France, several elements have created a political and regulatory context that is favourable to the development of the renewable energies:

- The European Directive on Electricity from Renewable Energies (RE) has been definitively adopted in September 2001. It sets the contribution of the renewable energies for France which should increase from 15 % in 1997 to 21 % in 2010;
- The National Scheme for the Improvement of Energy Efficiency (PNA2E) has been implemented by ADEME upon the government's request. The implementation of the FIDEME special fund (listed in the PNA2E) for subsidies granted to the SMEs will only become a reality in 2002, and only after obtaining the agreement of the European Commission;
- New purchasing rates have been proposed in October 2001 by the Ministry of the Industry for photovoltaic electricity: 0,15 EUR per kilowatt-hour in mainland France and 0,30 EUR per kilowatt-hour in the overseas departments and Corsica. These are regions where electricity is expensive to produce;
- In December 2001, EDF, the electricity company has officially presented, "Agenda 21," which defines the guiding principles of its actions and its decisions, thus making sustainable development a major strategic orientation. Renewable energies will have a part in this policy;
- Within the framework of the "Electricity Utility Company Modernization" law, a regulating authority has been established: the Electricity Regulation Commission (CRE). It has the task of monitoring the opening of the electricity market in view of guaranteeing fair competition and overseeing to service quality and electricity costs.

Within such a context, the French Agency for Environment and Energy Management (ADEME) has been able to strengthen the photovoltaic solar electricity (PV) promotion that the government has entrusted it with. Together with its financing partners, ADEME is preparing the launch of a new 5-year programme aiming at the implementation of 15 MW of grid-connected photovoltaic systems integrated into the buildings and involving a financial support on investment for 2002.

THE ADEME PROGRAMME

The strengthening of the renewable energies promotion that had been decided by the government in 1998 has allowed an increase of the ADEME intervention budget in the field of photovoltaic solar electricity since as early as 1999. This public intervention budget which is around 10 million euros a year, has been confirmed through the measures described above and should be increased again with the new programme in preparation for the dissemination of the PV systems connected to the grid. The ADEME's photovoltaic programme (www.ademe.fr) concerns two constituents of actions: the financial aids devoted to the RTD projects on the photovoltaic system components as well as the aids in support of the dissemination projects.

The research and technology development (RTD) actions undertaken by the industrial and public partners are designed for cutting the manufacturing costs of the different components and increasing their performance and quality.
In order to open the markets, ADEME's policy consists of providing, together with other partners, financial subsidies, specific technical and economical information and training for two types of applications:

- The photovoltaic system installations in isolated sites outside the electrical networks, in cooperation with the FACÉ fund, the regional authorities, EDF, etc.;
- The installation of photovoltaic systems integrated into buildings and connected to the grid: firstly, within the framework of a demonstration project financed by the European Commission and after, based on this experience, as part of a more ambitious programme of installation of grid-connected "photovoltaic roofs" which will be operational in 2002.

RESEARCH AND TECHNOLOGICAL DEVELOPMENT

Together with its industrial and public partners, ADEME has implemented long-term projects of research and technological development on the components and the systems. The objective is to cut the component's costs as well as the systems' operating costs, increase their performance, quality and reliability. The themes selected and the partners involved are the following:

- Materials and processes for the industrial manufacturing of multicrystalline silicon photovoltaic cells: " PV–16 " project (Photowatt International in co-operation with the public laboratories of the CNRS);
- Materials and manufacturing processes of thin film photovoltaic cells: 1) Monocrystalline silicon film: " Succes " project (Cea-Genec and INSA Lyon). 2) Heterojunctions based on amorphous and crystalline silicon: " Hermes " project (Cea–Genec and CNRS). 3) Cells based on Cu-In-Ga-Se prepared by electrodeposition: " Cisel " project (EDF-EMA, CNRS and Saint-Gobain Recherche). 4) Cells based on organic polymers (Cea-Lco, CNRS and Universities);
- Engineering of photovoltaic systems: management and control of the energy flows, converters, inverters (Apex Bp solar, Total Énergie, Transénergie, Cea-Genec, Armines, CNRS) ;
- Storage batteries adapted to photovoltaic applications: charge/discharge protocols, monitoring of ageing, reliability test, measure of the charge conditions (Ceac, Apex Bp Solar, Cea-Genec, CNRS) ;
- Multisource, stand alone village electrification systems for individual uses, water pumping (Transénergie, Total énergie, Armines, Cea-Genec) ;
- Accompanying studies on tests, return of field experiences, global management of the of PV systems network, granting of a concession, reliability of the systems and development of standards (Cea-Genec, Armines, PHK, IED, FONDEM, SERT, Costic, etc.).

Fig.1 - Hip-Hip Project, 35 kW, ST-Microelectronics, Grenoble

The French Atomic Energy Agency (CEA) has shown a voluntarist policy in the field of renewable energies through the creation of a programme dedicated to the new technologies of energy. The Genec laboratory (Genec) has integrated into its mission new research works on photovoltaic cells (see above) and has increased its headcount. The close collaboration established between the public research establishments CEA and CNRS on these new projects are giving a new impetus to the French photovoltaic research.

For its part, in June 2001, the CNRS has concluded the ECODEV multidisciplinary research programme on energy and the environment, and began a discussion on how to pursue its involvement in the photovoltaic sector.

The "Électricité de France" Company has been mobilizing on two activities. The research works on the Cu-In-Se thin films obtained by electrodeposition in cooperation with Saint-Gobain Recherche and the CNRS, and the International Standardization File. For the latter, since the " Technical Specifications for the Use of Renewable Energies in Rural Decentralised Rural Electrification " have been recognized as publication IEC-PAS 62111 of the International Electrotechnical Commission (IEC), a group for coordinating the technical committees IEC/TC82 (photovoltaic electricity), IEC/TC21 (storage batteries) and IEC/TC88 (wind energy) has been established in order to create the IEC 62257 Standard in this field.

IMPLEMENTATION

ADEME

In order to allow a coordinated action of the different public players in the photovoltaic sector, the ADEME has implemented outline agreements with the CEA, the CNRS and EDF.

As far as the subsidies provided for opening the market are concerned, the ADEME relies on partners such as the regional authorities with which State-Region plan contracts have been signed that include commitments in the renewable energies promotion programme.

The main sources of public financing that allow the installation of photovoltaic systems, are primarily the FACÉ fund and the Tax Exemption Law in the overseas departments. In addition, the complementary supports provided by the regional authorities, the ADEME, the European Commission and EDF (isolated sites in "urban scheme" which includes a subsidy lower or equal to 40 % of the cost of the installed system). The subsidy granted by the FACÉ fund is equal to 70 % of the cost of the installed PV system. The number of cases submitted to the FACÉ fund selection committee for the isolated sites in 2001 has declined against the previous year. This is due to saturation of the potential market. The average cost of the PV systems installed has decreased at 18-20 EUR per watt. The photovoltaic power installed and benefiting from the tax reductions entitled by the tax exemption law in the overseas departments (DOM) remains stable: about 800 kW per year.

For the grid-connected photovoltaic systems, the Hespul users' association still acts as a driving force in the promotion of projects that receive the financial support of the European Commission, the regional authorities and the ADEME: there has been about 300 kW installed during 2001, at an average cost of 7 EUR per watt.

On the other hand, also during 2001, the ADEME prepared an aid system aiming at the dissemination of grid-connected photovoltaic systems. This system should be operational in 2002. In this context, photovoltaic systems will be the subject of two types of support granted by the ADEME:

- Either for support of selected projects within the framework of European tenders restricted to 4,6 EUR per watt (basic grid-connected PV system) and 6,1 EUR per watt (grid-connected system with safety storage)
- Or within the framework of a subsidy, in the absence of European Commission financing on tenders, equal to 4,6 EUR per watt which could be increased to 6,1 EUR per watt in the case of a grid-connected PV system with safety storage. These levels should be taken as all public subsidies included. In mainland France, these aid rates will decrease as of 1 January 2005, at 3,8 EUR per watt (basic grid-connected) and 4,9 EUR per watt in the case of a grid-connected PV system with safety storage. A power ceiling will be applied, that is to say 5 kW for individuals and 30 kW in the community/tertiary sector. Beyond these ceilings, a case-by-case analysis will be carried out. The specifications established by the ADEME will determine the design, size and installation rules, as well as specific safety rules and technical measures for integration into the building, which is to be taken into account.

In any case, for the overseas departments, these aids will be granted, in the competitive sector, within the limits of the aid rate admitted by the local authorities (department counsels, regional authorities) calculated on the basis of the accepted costs and raised by 10 % for the SMEs.

Fig.2 - Rural electrification, Farm in Ombleze (Drôme), 1,8 kW. (photo Transénergie)

In continuing its role in information dissemination, the ADEME brought together all the players in the photovoltaic industry in France during two technical seminars: in June and in November 2001 at Sophia Antipolis, where 160 people became acquainted with projects now under way: field operations, specific R&DT studies and projects. The ISIS database, which includes the financial, technical and sociological data relating to the systems installed with the FACE public fund, has been presented to the profession.

The ADEME has published two booklets in 2001: 1) a bilingual guidebook containing recommendations on "The Protection of Photovoltaic Installations Against Lightning." This guidebook will fuel the discussions of the working group (Task) 3 of the International Energy Agency (IEA) Photovoltaic Power System Cooperation Programme and should become, after possible amendments, a guidebook with an international scope; and 2) an illustrated booklet on the "Applications of Photovoltaic Solar Energy," which describes the different uses of photovoltaic systems and includes technical and financial indications designed for local communities.

HIP-HIP DEMONSTRATION PROJECT

The " Hip-Hip " project benefits from the support of the European Commission: its aim is to install 500 kW of photovoltaic systems integrated into buildings and connected to the grid in each of the six participating European countries (www.hip-hip.net). In France, the players are Photowatt, EDF, Total Énergie, Apex Bp Solar, CSTB (Scientific and technical Centre of the Building industry), Genec, Hespul, Transénergie, IED and Sunwatt. In 2001, the power of the projects that has been subject to a participating agreement in France was 220 kW.
The majority of the installations are on slope roofs. They are broken down in equal share between new and old buildings and industrial and private buildings. The project is advancing according to the planned time schedule but the installed costs targeted at the end of the project had to be revised on the up side at 5,45 EUR per watt instead of 5,00 EUR per watt since the partners supplying the photovoltaic modules could not achieve the cost objectives initially set.
The work groups, which were the subject of studies between the partners, were: end-user issues, impact of the grid, non-technical barriers, certification of the systems integrated into buildings. The experience gained during the HIP-HIP project will be used as a basis for the new programme that the ADEME envisages to launch in 2002.

ÉLECTRICITÉ DE FRANCE

In 2001, EDF launched the ACCES (Access to Electricity and to Services) programme. ACCES consists of developing and implementing a group of profitable decentralized rural electrification projects in developing countries villages remote from the grid. Each project will lead to the creation of a DSC (Decentralized Services Company); a local structure for the exploitation of the services provided to the concerned populations. This resorts to local and renewable energies among which photovoltaic power is preferred. By year-end 2003, the ambition of ACCES is to allow access to electricity from more than 300 000 people within a selection of countries.

It should be recalled that in June 2000, the ADEME and EDF have signed a new outline agreement with a three-year duration, which aims at encouraging the development of energy efficiency, environmental quality and renewable energies. The agreement has raised 85 million Euros and is financed at parity by both partners.

INDUSTRY STATUS

In France, the photovoltaic industrialists continue their advance. In 2001, no new player had entered the sector.

PHOTOWATT

In 2001, this company defined new objectives together with its new management team. The production of photovoltaic cells was 13,4 MW in 2001 and the production rate at the year's end was 20 MW per year. The goal set is to reach a production level of 32 MW of photovoltaic cells per year in 2004. New manufacturing processes of cells emanating from the " PV-16 " R&TD project supported by the ADEME will be integrated into the production tool which will produce photovoltaic cells of a larger size (up to 15 cm x 15 cm), thinner (thickness smaller than 200 µm), with a better conversion efficiency (14 % to 15 %) and at a better direct production cost (under 1,2 EUR per watt).

FREE ENERGY EUROPE

This company manufactures about 500 kW of amorphous silicon modules with a stabilized power of 2 W, 4 W, 6 W and 12 W as well as several types of systems designed for rural electrification. New 19 W modules using tandem junctions have been tested in view of meeting the IEC 61646 International Standard requirements before being launched on the market as early as 2002.

TOTAL ÉNERGIE AND APEX BP SOLAR

These two photovoltaic companies specialize in the development of components and the sale of turnkey systems. They are closely involved in the ADEME's promotion policy together with their subsidiaries in the overseas departments and territories.

MARKET DEVELOPMENT

Global turnover of the main companies of the photovoltaic electricity industry had increased by 20% in 2001 and exceeded 120 million euros in 2001.

The peak power of the photovoltaic systems installed during the year 2001 was about 2 MW which brings the total operational capacity in France to 13 MW; of which almost 1 MW is part of grid-connected photovoltaic systems. However, the results for 2001 remain modest for the rural electrification projects outside the grid benefitting from a FACÉ fund financing. A decrease in the number of electrification projects can be observed, as most of the sites that could benefit from public aids have already been equipped. The new programme of dissemination of grid-connected PV systems prepared by the ADEME for 2002 will enhance the photovoltaic activity.

FUTURE OUTLOOK

The programme implemented 3 years ago by the ADEME and aimed at supporting the development of the photovoltaic power systems benefitted from new political and regulatory measures in 2001. The RTD effort has been pursued through a commitment on the new technology projects relating to the photovoltaic cells. The PNA2E national scheme, the European directive and the new photovoltaic solar electricity purchasing rates have allowed the ADEME to envisage new types of financial aids which should permit the launch of a dissemination programme of the photovoltaic applications connected to the grid. The installation, over 5 years, of 15 MW of grid-connected PV power systems is the goal set by the ADEME but the programme will only be launched in 2002. This new initiative has received a warm welcome from the photovoltaic industry.

GERMANY

"PV TECHNOLOGY - STATUS AND PROSPECTS"
CHRISTOPH HÜNNEKES, PROJEKTTRÄGER JÜLICH (PTJ),
FORSCHUNGSZENTRUM JÜLICH GMBH

GENERAL FRAMEWORK

The reduction of emissions of greenhouse gases is an important target of all environmental policies in Germany. It is expected that photovoltaics (PV) may contribute to this target in the long term. Therefore, research, development and demonstration in the field of PV are supported from several sides, especially the Federal Government, the Federal States, local authorities and utilities.

NATIONAL PROGRAMME

Within the Federal Government, the responsibility for applied energy research as well as the market introduction is with the Federal Ministry of Economics and Technology (BMWi). The basis for the German PV Research, Development and Demonstration (R,D&D) is the **4th Programme on Energy Research and Energy Technology.** Important parts of this programme, namely the development of techniques for an efficient use of energy and renewable energies are conducted by the Project Management Organization PTJ.
In 2001, federal support for R&D on PV amounted to about 29 mio EUR shared by 125 projects in total. The distribution of the budget to the various sectors of R&D shows that public funding is concentrated on the long-term options and activities to create a technological basis for small and medium sized enterprises whereas industrial R&D is directed to shorter term achievements.

In January 1999, the so called **"100 000 Rooftops Solar Power Programme"** came into force. It is expected that with support of this programme approx. 300 MW will be installed until the end of 2003. In addition to this programme, the **Renewable Energy Law** guaranteeing a feed in tariff of 0.51 EUR/kWh for PV works.

R,D&D

With a time horizon of ten years a so-called "Way Paving Programme Photovoltaic 2005," has been formulated in the 4th energy R,D&D Programme with three main goals:

- Cost-reduction for PV-cells and modules by decreasing production costs and by increasing cell and module efficiencies.
- Cost-reduction, technical optimisation and removing of other obstacles wich prevent the use of PV in different types of buildings.
- PV for decentralized, grid-independent electricity supply.

In the following, selected topics of important R&D activities in Germany are described.

Crystalline Silicon

Crystalline silicon is still the most important material for manufacturing solar cells. Today, emphasis is put on efficient manufacturing techniques. In 2001 new R&D activities are focused on:

- the improvement of EFG ribbons (EFG - Edge-Defined Film-Fed Growth),
- an improved crystal growth concept for ingot casted silicon and
- innovative production systems for solar cells, e.g. Rapid Thermal Processing (RTP), In-line plasma processes, LED-Flasher systems.

Fig. 1 - Production line for CIS solar cells (photo Würth Solar GmbH&Co. KG)

The aim is to strengthen technologically oriented small and medium sized companies and by this, to create a productive supply industry.

Thin Film Technologies

Thin Film Technologies have the potential to combine low material- and energy-consumption with simple process technologies resulting in a cost-effective large area production. Today, several materials are used and a lot of cell concepts with different maturity are existing:

TECHNOLOGY	NEW R&D ACTIVITIES WITH FEDERAL SUPPORT
Currently amorphous Silicon (a-Si) has the highest technological maturity. In Putzbrunn RWE Solar GmbH is running a small production line.	development of improved deposition techniques
Thin Film Solar Cells on basis of CuInSe2 (CIS) have been developed in Germany for years. Currently Würth Solar GmbH&Co. KG is operating a first pilot production line (Fig. 1).	development of efficient deposition techniques
Antec Solar is running a Cadmium Telluride (CdTe) pilot plant in Rudisleben, State of Thuringia.	
A very promising technique seems to be the crystalline Si thin film cell.	joint R&D project to develop efficient deposition techniques on large substrates, development of ceramic substrates

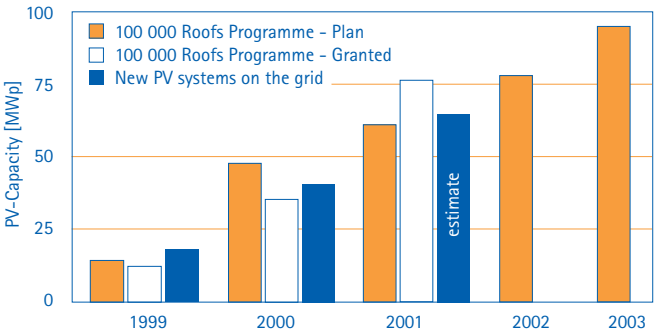


Fig. 2 – 100 000 Rooftops Solar Power Programme

System Technology

Beside the ongoing development of modular PV system technology, including features supporting communication and power management, the evaluation of PV-systems is a topic of interest. The corresponding activities to the latter are partly carried out under Task 2 of the IEA-PVPS programme.

Demonstration

Today, the Renewable Energy Law together with the "100 000 Rooftops Solar Power Programme" is the driving force for the development of the German PV market. Consequently, demonstration projects play a minor role within the current R,D&D-programme.

IMPLEMENTATION

In the last several years, Germany has executed important programmes in the field of PV which have triggered remarkable results in market development and technology progress. Complementary to the R,D&D-programme, new PV-funding sources with growing importance, mainly in the area of market introduction have been established:

- The "Electricity Feed Law," introduced in 1991, was replaced by the **"Renewable Energy Law,"** in April 2000. The new law rules the input and favourable payment of electricity from renewable energies by the utilities. For PV systems built before the end of 2001, a feed in tariff of 0.51 EUR/kWh will be paid.
- In January 1999, the **Federal Ministry of Economics and Technology** (BMWi) started the "100 000 Rooftops Solar Power Programme." Until November 2001, almost 37 500 applications were received and a total capacity of 126 MWp was granted (see Fig. 2). The programme is a soft loan programme (current rate of interest 1.9% per year) and will last until 2003. Applications can be filed by small and medium enterprises as well as by individuals. The BMWi offered a budget of approx. 460 mio EUR for the whole period of this programme.
- Moreover, the BMWi supports the application of renewable energies (solar-thermal, geothermal, biomass etc.) with soft loans or subsidies. The PV initiative, **"Sun at School,"** is part of this programme.
- Some of the **Federal States** (Länder) have defined their own programmes, mainly to support the application of renewable energy and energy conservation.
- The **Federal German Environmental Foundation** (DBU) supports development and demonstration in the field of renewable energy sources and energy conservation.
- A number of **utilities** have launched initiatives to build PV-demonstration and pilot systems or to provide advice and information. In a growing number of cases, financial support for the rational use of energy and for renewable energies is provided. **Cost-effective payments** for every kilowatt hour of energy fed into the public grid from PV and other renewable energy systems is offered by some utilities belonging to cities and communities.

INDUSTRY STATUS

Over the years, an industrial infrastructure has been created with the main focus on crystalline Silicon technologies. However, as almost everywhere, the PV market still strongly depends on governmental support.

Following an estimate of the German Federal Association Solar Energy (BSE), approximately 3 300 employees were working in the field of PV at the end of 2001; most of them were involved in the installation of systems.

MARKET DEVELOPMENT INCENTIVES

The programmes described above have accelerated the installation of PV-systems in Germany significantly (Table 1). Following a first estimate there could be roughly 165 MWp on the grid at the end of 2001. Moreover, it is expected that this capacity will increase steadily within the next years due to the "100 000 Rooftops Solar Power Programme" together with the Renewable Energy Law.

FUTURE OUTLOOK

Following the guidelines of the "100 000 Rooftops Solar Power Programme" for the coming years, the installed grid connected PV capacity is expected to increase steadily (see Fig. 2 also):

2002	+ 80 MWp
2003	+ 95 MWp

TABLE 1 CUMULATED GRID CONNECTED PV POWER IN GERMANY

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
PV power (MW)	1.5	2.5	5.6	8.9	12.4	17.8	23.8	34	43	55	100	165

ISRAEL

PV TECHNOLOGY STATUS AND PROSPECTS: AN UPDATE
BY DR. H. AVRAHAM ARBIB, DIRECTOR, DIVISION OF R&D,
MINISTRY OF NATIONAL INFRASTRUCTURES

GENERAL

Photovoltaic activity in Israel continues to be concentrated mainly in academic research, with limited industrial involvement. The ubiquity of the electricity grid makes most applications non-cost-effective, except in unique situations.

About 440 kWp have been installed so far; 40 kWp were installed in 2000. Nearly all the applications are off-grid remote electrification systems. Most installations were made on an economic basis, the PV system being the most economically viable alternative (because of its distance from the electric grid).

The Israel Electric Corporation is required to purchase electricity from private producers, according to rules set by the Ministry of National Infrastructures. There are no promotion initiatives or subsidies for PV systems. However, there are indications that public perception of renewable energy is becoming increasingly positive. As a result, both the Government and the Israel Electric Corporation are studying net-metering schemes and revising regulations to enable power buy-back.

There are no special regulations relating to PV systems, although the Israel Electric Corporation has general guidelines relating to the quality of the electricity it purchases.

Figure 1. Small PV system powering an irrigation computer (Interdan).

INDUSTRY INVOLVEMENT

A few firms are active in the PV field, and they deal mainly with system integration. Most companies are small, and are not exclusively dedicated to PV. Some of the local production of systems is exported.

Presently, there is no local production of PV cells nor inverters. Israel has the required technological infrastructure enabling it to produce all the components needed for integration in PV systems. However, due to economical considerations, components such as modules are imported. In spite of this, some unique Israeli PV systems have high added value related to the balance of system (in particular, control systems), and therefore, they have international market potential.

RESEARCH AND DEVELOPMENT

More than fifty research teams are involved in photovoltaic R&D, most of them from academe, spread over most research areas (with no concentration of effort on particular subjects). Many of these teams cooperate with leading teams worldwide (both in academe and in industry).

Among the current R&D projects, a number are highly innovative and worth noting:

The possibility of making thin-film solar cells from carbon, in its new form of buckminsterfullerene (C_{60}), is being investigated at the National Solar Energy Center in Sde Boker;

A team at the Jerusalem College of Technology is working on the development of solar cells for efficient conversion of highly concentrated radiation, whose strong point is simplicity of fabrication;

A project underway at the Technion, Haifa, has the goal of achieving a new type of cheap and stable silicon cells.
The cells are an admixture of micro-crystalline hydrogenated silicon and amorphpous hydrogenated silicon, optimized to absorb maximum light and to be as stable as crystalline silicon. The research is carried out in collaboration with German partners.

Performance of various photovoltaic modules under desert conditions is being monitored at the National Solar Energy Center in Sde Boker.

DEMONSTRATION SYSTEMS

A number of projects are underway, and the following are particularly worth mentioning:

The Israel Electric Corporation has installed a 5 KWp grid-connected PV system on a house in Mitzpe Adi in the Galilee, at a total cost of 100 000 USD. When the system produces more electricity than is being used in the home, electricity can be added back into the power grid. Operation has been practically trouble-free for the last five years. Overall efficiency is about 10.3% (AC).

At Kibbutz Samar in the Arava Valley (Negev Desert), the first 4.5 kWp of a planned 200 kWp project have been built. The system

claims the lowest ever balance of system (BOS) for a grid-connected project. Computer simulations of system performance were run by the Ben Gurion National Solar Energy Center, based on ten years of hourly recorded data gathered five kilometers from the site.

In a cooperation project within the EU 4th Framework Programme, the Israel Electric Corporation has built a reverse-osmosis (R.O.) desalination plant, powered by wind and PV generators. The purpose of the project is to investigate the energy balance of a renewable energy hybrid system connected to a battery bank. The PV array capacity is 3.5 kWp, and the desalination unit can provide 400 L/h. The system was erected in Kibbutz Ma'agan Michael (30 km south of Haifa), where a brackish water source is available. The unit will represent a fresh water source for a small and remote community, and the project concentrates on aspects such as meeting the community daily water needs, reliability and economics.

Tel Aviv University is planning a 45 kW grid-connected system on the facade of a new building.

EDUCATIONAL ACTIVITIES

In the Nitzana youth village in the Negev desert, an educational project was started, called "Science Following the Sun." The project brings the message of solar energy, including photovoltaics, to hundreds of school children.

GOVERNMENT ACTIONS

No special plans are being considered by the Government for the near future. However, a number of actions are being taken to encourage the PV activity. Among them:

- Keeping the R&D excellence centers alive through selective Government support of projects. The R&D expenditures in photo voltaics of the Ministry of National Infrastructures were 225 000 USD in 2001; however, additional funding is available in this area from various research foundations.
- Supporting grid-connected demonstration projects by 30% of investment when it can be proven that this is enough to make the project cost-effective.

ITALY

PV TECHNOLOGY STATUS AND PERSPECTIVES
S. CASTELLO, ENEA
S. GUASTELLA, CESI

GENERAL FRAMEWORK

Italy has been widely involved in a photovoltaic program, ranging from research on materials to the development of medium and large grid connected power plants. ENEA (the Italian Agency for New Technology, Energy and Environment), CESI (Institute for Research and Certification of Electric Components and Systems), ENEL Green Power (ENEL Group) and some Italian PV industries have been the most active operators.

As a consequence of the electrical market liberalization, CESI has acquired from ENEL (year 2000) its R&D activities in generation, transmission, distribution, end-use of electricity, environment and renewable energies and is carrying out studies and experimental activities, in the sector of photovoltaic systems, on behalf of the Italian Ministry of Productive Activities (formerly Ministry of Industry). In 2001, ERGA spa (now ENEL Green Power Spa), a company established by ENEL for business on the renewable energy market, confirmed its position as the world's largest company dedicated exclusively to renewable energy. ENEL has also entered into the North and South American market with its acquisition of the CHI Energy company and its recent acquisition of EGI (Energia Global International).

As it has already occurred in other countries which are deeply involved in PV, a national roof-top Programme has been now started in Italy. This Programme, initially conceived by the Ministry of Productive Activities, is at present funded by the Ministry of Environment and the Italian Local Authorities. Moreover, the Programme was completely defined in December 2000 and launched in March 2001, as part of a broader programme towards the diffusion of photovoltaic technology in Italy.

On the technology side, crystalline silicon cells and amorphous silicon integrated modules are developed by ENEA, while an international cooperation programme is carried out in the field of heterojunction.

From the systems point of view, the total cumulative PV power installed in Italy was expected to be about 20 MWp at year-end 2001. Rural electrification, off-grid domestic applications, on-grid centralized systems and on-grid distributed systems constitute the most important sectors of the Italian market, which is still showing a behavior strongly dependent on subsidized projects.

NATIONAL PROGRAMME

The Italian roof-top Programme is devoted to the realization of grid-connected photovoltaic systems, ranging from 1 kW to 20 kW and preferably integrated in building structures. The purpose is to promote a wide diffusion of building integrated photovoltaic applications all over Italy and to create a sure and lasting market, in order to allow companies for long term investment planning.

In addition, some long term benefits are expected concerning a decrease of photovoltaic costs, the creation of job opportunities and the local development in unfavoured regions.

A total budget of 31 mio EUR has been provided by the Ministry of Environment, for the period 2001 - 2002, in order to finance the national roof-top Programme. During this initial phase, two Sub-programmes have been started.

The first one, funded by about 10.3 mio EUR and managed by the Ministry of Environment, is almost concluded and is addressed only to Public bodies, such as Local Authorities, Universities and Research Institutions. More than 200 PV installations have been approved, for a total capacity of about 1.8 MW.

During the period April – June 2001, 586 applications have been submitted to the Ministry of Environment in the framework of the first Sub-programme. The corresponding requested power sums of up to 6.6 MW with a demand of more than three times the offer, in terms of both power and public contributions were requested. However, because of this real success, additional funds have been made available by the Ministry of Environment to finance (with a share of 50%) applications coming from those Regions, that will provide the rest of funds.

The second Sub-programme, addressed also to citizens and private companies is composed of 21 local Programmes. In fact, the nineteen Italian Regions and the two Autonomous Provinces of Trento and Bolzano have agreed to jointly fund the initiative, providing in total 9.3 mio Euro; corresponding to about 30% of the total of the public incentives. The remaining 70% (i.e. 20.7 mio EUR) is still coming from the Ministry of Environment. Ministerial funds have been shared proportionally among participants with their populations.

The main objective of this Sub-programme is to realize about 1800 plants by 2002, with a total capacity of around 5 MW. Most Region and Autonomous Provinces have issued their announcements during the period August – September 2001, while the deadline for application submission has ranged from October to December 2001.

In general, contributions of up to 75% of the eligible investment cost can be provided by both Sub-programmes. The maximum investment cost has been fixed at about 8 EUR/W, for photovoltaic plants ranging from 1 to 5 kW. In the range from 5 to 20 kW, the maximum investment cost is decreasing to 7 EUR/W.

It is worth mentioning that only the first Sub-programme incentive photovoltaic installations in Natural Parks as well as good quality really integrated systems, admitted an increase up to 20% of the above investment cost. However, in the framework of the second Sub-programme, priority is given to fully integrated roof-top applications.

On the whole, the Ministry of Environment incentives activated an invested amount of about 53 mio EUR in order to realize more than 2 000 plants; with a total installed capacity around 7 MW.

In this scenario, ENEA has been requested to provide the technical support to the Ministry of Environment in the definition, management, data monitoring and reporting of the two Sub-programmes. Besides, ENEA will provide, in the framework of its R&D activities on distributed generation, the scientific and technical support, contributing to reach the long term objectives of the initiative.

R&D AND DEMONSTRATION

Most of these activities are carried out directly by ENEA in its own laboratories, some others have been conducted by CESI in laboratories and in the field, while some specific topics are studied in cooperation between ENEA and the PV industries.

PV facade on ENEA-Portici laboratories

Tests on innovative photovoltaic modules at CESI laboratories

Activities on material and devices are focused on a-Si/c-Si heterojunction, developed in ENEA Portici Laboratories for future industrial applications. Interesting results have demonstrated the feasibility of the process on full size multicrystalline substrates with an efficiency of 13%. Moreover, to improve the efficiency and stability of devices, both single-junction and tandem structures are investigated at Portici Laboratories. The process steps for an amorphous p-i-n solar cell exceeding 11% efficiency have been scaled-up to a large area reactor allowing for the fabrication of a 900 cm module with an initial efficiency of 8.5% and a stable efficiency of 7.3%. At the ENEA Casaccia Laboratories, crystalline silicon devices based on laser assisted processes or on advanced screen-printing technologies have been currently realized with efficiency greater than 17% and 16% respectively.

At CESI laboratories, research studies have been carried out on high efficiency GaInP2/GaAs/Ge triple junction photovoltaic cells. These studies, which make use of CISE (now incorporated in CESI) experience on the fabrication of photovoltaic cells for spatial applications, are aimed at the development of GaAs-based cells whose cost could justify their terrestrial application.

Moreover, in the field of a-Si/c-Si heterojunction, a cooperation between Eurosolare, ENEA and some other European operators, is currently being carried out in the framework of the "MOPHET" Programme which is promoted by the European Community.

In the field of systems and components, activities on small grid-connected plants, such as prototypes of roof mounted systems are carried out by ENEA in the Manfredonia test facility and in the Portici Center. Performances of these plants are analyzed in terms of energy output, energy losses, power quality, operation and maintenance procedures.

Analysis and tests on medium and large power plants have been carried out by ENEA on Delphos 600 kWp (1 unit of 300 kWp and 3 units of 100 kWp, called PLUG) and Casaccia 100 kWp grid-connected plant.

Furthermore, performance evaluations of photovoltaic components and plants have been carried out by CESI on several PV plants owned by the ENEL Group (located throughout the Italian territory), in order to assess long term behavior of PV technology in different climatic conditions and in different electric configurations.

In the framework of preliminary activities foreseen by the Italian Roof-top Programme, the realization of 4 (out of 18) small pilot plants, for a total capacity of about 40 kWp has been completed in 2001. The data collection and performance analysis are now being carried out by CESI and ENEA.

INDUSTRY STATUS

The Italian PV industry consists of two major module manufacturers, some inverter manufacturing firms and several industrial operators in the field of design, construction and commercialization of PV systems.

The major PV module manufacturer is Eurosolare with a staff of about 70 people. Its manufacturing facilities have a production capability of 3 MWp/year per shift. Both single-crystal and polycrystalline silicon cells are currently produced. The Eurosolare polycrystalline module manufacturing process is completely integrated starting from the ingot fabrication while single crystal modules use wafers bought on the international market. Eurosolare production includes also specially designed modules for roof tops and facades. Overall, the Eurosolare module production has been of 4.4 MWp (0.5 MWp as single crystal) in 2001.

The second Italian module manufacturer is Helios Technology. Its manufacturing facilities have a production capability of 2.5 MWp/year. In 2001, the Helios Technology module production was expected to be 2,2 MWp. Helios Technology module manufacturing process comprehends the fabrication of cells and modules from mono-crystalline silicon wafers.

In the field of PV systems, it is worth mentioning that both Eurosolare and Helios Technology activities include the commercialization, design and turnkey supply of PV systems. Other industrial operators in this field are A.N.I.T., Gechelin Group, SEI, Artistica and all the companies included in the Italian PV Firms Group (GIFI).

MARKET DEVELOPMENT

The total PV power installed in Italy in 2001 was expected to be about 20 MWp. In particular, rural electrification (about 6.3 MWp), off-grid domestic applications (about 5.3 MWp) on-grid centralised systems (about 6.7 MWp) and on-grid distributed (about 1.7 MWp) results constitute the most important sectors of the Italian market. Up until now, the national PV market has been showing behaviour that is strongly dependent on subsidised projects. In particular, the sector of PV plants for power generation has been powerfully boosted by the financial support coming from the government, the European Community, ENEL and ENEA projects.

FUTURE OUTLOOK

Because of the success of the Italian roof-top Programme obtained up to now, and in accordance with the Italian and European strategy on CO2 emission reduction, an additional support of the Italian Government to finance the roof-top Programme is expected in the following years.

JAPAN

PV TECHNOLOGY STATUS AND PROSPECTS
KEN-ICHIRO OGAWA, NEDO

Fig. 1 - Building material integrated PV system (9.5 kW) and light transparent type PV cell (1.9 kW)

GENERAL FRAMEWORK

The promotion and deployment of photovoltaic (PV) systems have been implemented through the foresight for new energy in "The Total Primary Energy Supply Outlook" prepared by the Advisory Committee for Energy. The Outlook was reviewed in 2001 and the target for PV system introduction by FY2010 was revised to 4 820 MW from 5 000 MW. The Ministry of Economy, Trade and Industry (formerly the Ministry of International Trade and Industry) have been actively driving forward the promotion measures and policy for research and development for PV systems to achieve the introduction target. "The New Energy Law" established in 1997 stipulates the responsibility that national and local governments, energy consumers, energy suppliers and energy equipment manufacturers should be taking in order to introduce and expand new energy. In addition, the "Law Concerning Promotion Measures to Arrest Global Warming" and the "Law for Green Purchase" were enacted.

NATIONAL PROGRAMME

The Government has implemented R&D, demonstration tests and promotion policies towards the achievement of targeted installed capacity of 4 820MW of PV systems by FY2010. In the field of R&D, technical development for cost reduction of PV systems and technology development for PV promotion are being done. Regarding demonstration tests, the following have been continued: the cost reduction demonstration test by standardization of PV systems for industrial use aiming at introduction and promotion of PV systems to private facilities and the demonstration test for new types of PV systems. As to promotion policy, the Residential PV System Dissemination Programme has been strongly moved forward. In addition, the Government has implemented supporting programmes for the introduction of new energy to local governments and private entrepreneurs.

The budgets for FY2001 of major National PV Programmes are as follows:

1. Photovoltaic power generation technology research and development: 5 050 MJPY
2. Technology development to deploy PV system: 1 310 MJPY
3. Residential PV System Dissemination Programme: 23 510 MJPY
4. Field Test Programme for industrial use: 1 990 MJPY
5. Financial support for entrepreneurs introducing new energy: 14 040 MJPY
6. Introduction and promotion of new energy at regional level: 11 500 MJPY
7. Support for local efforts to develop the vision of new energy use and energy savings: 1 230 MJPY
8. Support for local activities for new energy: 150 MJPY
9. Support for local activities to introduce new energy new): 910 MJPY

The budgets for items 5, 6, 7, 8 and 9 include ones for PV and others for new energies.

R&D,D

The New Sunshine Project established in FY1993 to promote a comprehensive, long-term R&D has been completed, and a new technological programme was initiated in FY2001, based on the results obtained thus far.

The new "5-Year Plan for Photovoltaic Power Generation Technology Research and Development (FY2001-FY2005)" programme aims mainly at: improving the efficiency of R&D through "selection and concentration" of R&D themes; the early establishment of PV technology for the realization of approximately the same generation cost as the electricity rate for households; developing common basic technology necessary for full-scale deployment of PV applications; and developing essential technologies, PV cells and PV systems based on new conceptions. The development objectives of the programme are classified in the field of technology R&D as follows; the short- and medium-term targets are (i) the development of advanced PV cells, (ii) the development of technology focused on PV promotion, and (iii) the development of common basic technology necessary for full-scale deployment of PV applications. The long-term target is technology R&D on innovative next generation PV systems.

The main demonstration programme implemented by the Ministry of Economy, Trade and Industry (METI) in FY2001 was the "PV Field Test for Industrial Use."

PV Field Test for Industrial Use

This programme was started in FY1998 and is now entering its 4th year. Its aims are; (i) to install new types of PV system including building integrated PV systems and standardized PV systems with 10 kW power units in various applications for the industrial sector; (ii) to analyze the data collected under a long-term operation and to get ahead on introduction and expansion of PV systems in the industrial sector and (iii) to realize price down by standardization. Private companies, local public organizations and other organizations are eligible for subsidy. Half of PV installation costs are subsidized. 73 PV systems, totaling 1 940 kW in FY1998, 93 PV systems, totaling 2 790 kW in FY1999, and 149 PV systems, totaling 3 680 kW in FY2000 have been installed. In FY2001, 225 PV systems, 5 210 kW in total were accepted.

PV Field Tests for Public Facilities implemented since FY1992 achieved successfully the expected target and were completed in FY1997. Only acquisition and canalization of the operation data have been continued since FY1998 and were to be completed in FY2001. 1 830 PV systems, 4 900 kW were installed at schools, welfare facilities, factories, office buildings, private facilities under PV Field Tests for Public Facilities.

IMPLEMENTATION

1. The Ministry of Economy, Trade and Industry

The main implementation programmes that were carried out in FY2001 were the "Residential PV System Dissemination Programme," the "Introduction and Promotion of New Energy at the Regional Level" and the "Financial Support for Entrepreneurs Introducing New Energy."

Residential PV System Dissemination Programme

The "Residential PV System Monitor Programme" initiated in FY1994 was renamed the "Residential PV System Dissemination Programme" in FY1997 in an effort to develop the initial residential PV system market. The number of installations exceeded 50 000 systems.

The "Residential PV System Dissemination Programme" aims at reducing the expenses of PV system installers and creating an initial PV market through subsidizing the installation cost for residential PV systems. The subsidy is given in three categories, (i) to an individual who is going to install a PV system to his own house, (ii) to ready-built house suppliers of housing development complexes and (iii) to local public organizations who are going to introduce PV systems to public housing. PV systems with reverse flow connected to low voltage lines are subsidized. Subsidy in FY2000 was provided for 270 000JPYkW (up to 10 kW) in the first half, and for 180 000JPY/kW (up to 4 kW) in the second half, but the subsidy in FY2001 was decreased to 120 000JPY (up to 9.99 kW) through the year.
Residential PV systems have been installed to 15 879 houses, total 57.7 MW in FY1999, 6 352 houses, 24.1 MW in FY1998, to 5 654 houses, 19,5 MW in FY1997, to 1 986 houses, 7,5 MW in FY1996, to 1 065 houses, 3,9 MW in FY1995 and to 539 houses, 1,9 MW in FY1994. In FY2000, 25 741 houses were accepted, and as of December 28, 2001, 20 043 houses were accepted.

Introduction and Promotion of New Energy at the Regional Level

This project aims at accelerating new energy introduction by supporting the regional projects that local governments established for new energy. Subsidy is provided for local public organizations who are going to introduce and promote PV, wind power, solar heat, differential temperature energy, natural gas co-generation, fuel cell, wastes generation, use of waste heat, production of wastes fuel, clean energy car, energy saving measurements. A PV system is subsidized to 150 kW output and over. Half of the system installation cost is subsidized. 16 systems in total were subsidized in FY1998, and 4 systems out of them were PV systems. The total capacity installed was 500 kW. 37 systems in total were subsidized in FY1999, and 19 systems out of them were PV systems. The total capacity installed was 1 580 kW. In FY2000, 28 systems in total were qualified and 14 systems out of them were PV systems. Total capacity installed was 1 885 kW. In FY2001, 37 systems in total were qualified and 15 systems out of them were PV systems. Total capacity installed was 3 074 kW.

The programme allows local governments to introduce PV systems selectively to school buildings and public facilities.

Financial Support for Entrepreneurs Introducing New Energy

This programme aims at accelerating new energy introduction by supporting the industrial entrepreneurs who set about introducing new energy, such as PV, wind power, solar heat, differential temperature energy, natural gas co-generation, fuel cell, wastes generation, use of waste heat, production of wastes fuel, from a viewpoint of energy security and global environmental protection. The private entrepreneurs who set about new energy business are eligible for guaranteed debt or subsidy. A third of system installation cost is subsidized and guaranteed debt is 90% of a debt. The capacity of an eligible PV system is 100 kW and over. 18 systems in total were qualified in FY1998 and one system out of them was a PV system with 116 kW. 32 systems in total were qualified in FY1999 and one system out of them was a PV system with 100 kW. In FY2000, no PV system was qualified. In FY2001, 34 systems in total were qualified and one system out of them was a PV system with 140 kW.

In addition, support has been given to the projects so that local governments develop their vision for the introduction of new energy at the local level, and, to NGOs' supporting activities to introduce new energy at the local level.

Fig. 2 - 84.7 kW Grid-connected PV system using ribbon type multi-crystalline silicon

Fig.3 - 60 kW curtain wall type PV system and 16.7 kW skylight PV system.

2. The Ministry of Land, Infrastructure and Transport (formerly the Ministry of Construction)

Under the "Guidelines for Planning Environmentally Friendly Government Facilities (Green Government Office Building)," construction of green government office buildings with PV system have been promoted.

3. The Ministry of Posts and Telecommunications

The Ministry initiated the "Environmentally-Friendly Facilities Provision Project" for the purpose of environmental protection in the community and is promoting the introduction of PV systems to post offices.

4. The Ministry of Education, Culture, Sports, Science and Technology (formerly the Ministry of Education)

The Ministry continues the "Eco-school Promotion Pilot Model Project" initiated in partnership with MITI (then) in FY1997 and is promoting the introduction of PV systems to elementary and junior high schools in Japan. 99 schools throughout Japan were designated as pilot model schools by FY2000, and 75 schools are scheduled to install PV systems with 10 kW and over.

5. The Ministry of Environment (formerly the Environment Agency)

The Ministry is promoting a project on CO2 emission reduction measures by use of natural energy under the "Basic Guideline for Promotion Measures to Arrest Global Warming" established in FY1986. In addition, the "Law for Green Purchase" came into force in April 2001, and commodities procured by the Government have to be replaced by environmental friendly products. Since PV systems are specified as special procurement products, the introduction of PV systems to national facilities is expected to increase.

6. The Local Governments and Municipals

As movements to grapple positively with environmental issues are spreading, there is an increase in some local governments and municipals to plan and implement the introduction of PV systems and develop their own plan under the Regional New Energy Introduction Vision. Some local governments and municipals also provide their own additional subsidy to public financing and their number is increasing year by year. Promotional supports to PV systems are enhanced at the level of local governments and municipals. As of April 2001, local governments who provided the subsidy for residential PV systems totaled 114 municipalities.

7. Utilities

Electric power companies continue the introduction of PV systems to their own facilities, and the net metering system with buy-back contracts for surplus PV electricity at the same rate as selling. As of the end of March 2000, the capacity installed to their facilities was 4 558 kW and the power bought by buy-back contract totaled 72 087 000 kWh.

10 electric power companies in Japan established the "Green Power Fund" in October 2000, aimed at introducing and promoting PV systems and wind power systems. Electric power companies bill an additional charge as a contribution of 500 JPY/share/month to their supporters among their customers, and contribute the same endowment as the amount of their supporters' contribution. The fund is used for installation of PV systems and wind power systems. In 2001, 39 public facilities throughout Japan, including schools, were subsidized through the Fund. The total capacity installed is 829 kW.

8. Financial Institutions

Some financial institutions, including banks, provide preferential financing at a low interest rate with the introduction of a residential PV system for private use.

INDUSTRY STATUS

For several years, the PV industry has been rapidly growing through the measures of the "Residential PV System Dissemination Programme" and the "Field Test Programme for Industrial Use" by METI. Especially, the market for residential PV systems has been remarkably growing and playing a role of pushing the PV market in Japan. The annual production of PV cells in Japan increased from a 50 MW level in 1998 to a 100 MW level in 2000 and maintains its rising trend.

The main PV cell manufacturers are Sharp, Kyocera, Mitsubishi Electric, Sanyo Electric, Canon, Ka-neka, Matsushita Seiko, Matsushita Battery, Showa Shell Sekiyu and MSK. Furthermore, Kobe Steel and Kawasaki Heavy Industries have recently entered into the PV market in cooperation with overseas manufacturers. Mitsubishi Heavy Industries is planning to enter into the PV market as well. To correspond to the recent increase in PV cell demand, PV cell manufacturers in Japan have been positively expanding their production capacity. Sharp expanded their annual production capacity to 94 MW in 2001 and is planning a further increase in 2002. Mitsubishi Electric also expanded their annual production capacity to a 25 MW scale. Sanyo is constructing a new plant with an annual production capacity of 14 MW. Kawasaki Steel started commercially to produce Si feedstock for PV cell manufacturers. Furthermore, major housing manufacturers decided to adopt PV systems one after another since the Ministry of Construction approved PV modules as building materials, and to commercialize "the houses equipped with PV system as a standard specification." Especially Sekisui Chemical focuses on the sales of the houses equipped with PV systems as standard specifications. They succeeded in receiving an order for 10 000 houses in 2001. House roof installation maker, KUBOTA succeeded in receiving an order of roof-integrated PV systems for all 97 houses in housing

TABLE 1 SHOWS THE CUMULATIVE INSTALLED PV POWER IN 4 SUB-MARKETS.

sub-market application	1992 kW	1993 kW	1994 kW	1995 kW	1996 kW	1997 kW	1998 kW	1999 kW	2000 kW
off-grid domestic	150	200	250	300	350	400	450	500	550
off-grid on-domestic	15 260	19 170	23 260	29 360	35 890	44 900	52 300	56 200	61 350
on-grid distributed	1 220	2 300	5 130	10 820	20 500	43 100	77 750	149 000	252 700
on-grid centralized	2 370	2 600	2 600	2 900	2 900	2 900	2 900	2 900	2 900
TOTAL	19 000	24 270	31 240	43 380	59 640	91 300	133 400	208 600	317 500

and lot developments. Besides the above-mentioned manufacturers, there are also building material manufacturers, who produce roofing materials, outer wall materials and sheet glasses, and commercialize building materials integrated with PV cells. Moreover, some builders start to construct buildings integrating PV cells as "environmental co-existence" buildings. As previously noted, industry from different fields is commercializing products with PV cells, and therefore, the range of the PV industry is expanding.

MARKET DEVELOPMENT

The initial market development for PV systems has increasingly made progress, in the market sector of private houses, public facilities, industrial facilities, traffic facilities, railroad facilities and commercial buildings through financial support to PV systems of METI. Especially in the housing sector, marketing to new and existing houses is in satisfactory progress. The market scale of 3-5 kW residential PV systems has expanded to annual sales of 30 000 systems. Also, in the sectors of public facilities, industrial facilities, commercial facilities and commercial buildings, the standardization of PV systems of 10 100 kW scale and development of novel type PV systems are being promoted. The market size for these sectors is estimated to be 500 to 1 000 systems annually. To correspond to the demand of above-mentioned sectors, PV cell manufacturers and building material makers commercialize thin type modules, lightweight modules, triangle modules, trapezoid modules, lighting type modules, coloured modules, flexible modules, roofing integrated modules, wall material integrated modules, and bifacial generation modules which meet user's needs to improve design and function. Furthermore, there is a widespread trend that local governments enhance possibilities to install PV systems on schools, governmental offices, welfare facilities, hospitals, and community centers. Private enterprises are also promoting to apply PV systems to rooftops and roofs of their head office buildings, business offices, factories and warehouses. Some private enterprises are planning to introduce PV systems in a timely manner to restraints, railway stations, service stations, etc.
Additionally, off-grid non-domestic PV systems without governmental support are actively utilized as commercial power supply sources for telecommunications, traffic signs, telemetering, ventilating fans and lighting.

FUTURE OUTLOOK

With backing to promotion and deployment of PV systems, publicity activities, promotional measures to arrest global warning, green purchase activities implemented by the Government's policy, individuals, the government offices, local governments and private entrepreneurs have promoted a better understanding of the introduction of PV systems. With the growth of the PV market, PV cell manufacturers make an effort to expand their production capacity and to reduce PV system cost. The roofing industry, building material industry, housing industry, construction industry and power source equipment industry are stimulated to enter into the PV market. These sectors are expected to play an essential role in promoting PV systems as a go-between for the PV industry and end users. Therefore, the PV market, especially for residents, public facilities, commercial buildings and industrial facilities, will be deploying more and more, and is expected to grow to a self-sustaining market in the near future.

METI is planning to prepare new systems such as a renewable portfolio system in order to achieve the introduction target of new energy by 2010.

Fig.4 - 630 kW PV system, PV monument "Solar Ark"

KOREA

PV TECHNOLOGY STATUS AND PROSPECTS
JINSOO SONG, KOREA INSTITUTE OF ENERGY RESEARCH (KIER)

1.5 kWP PV system for forest fire observation towers CCTV.

GENERAL FRAMEWORK

The Korean National Photovoltaic Programme has taken on new momentum since the inception of the "10 Years Long-Term Plan" and the renewed "Promotion Act NRSE Development, Utilization and Dissemination" from 1997. The major objective of the renewed plan is to meet a 2.0% share of total energy demand by renewable energy supplies to secure the stability of long-term energy demand and to cope with a recent serious environmental situation.

However, the PV market is still limited in size and its application sector is largely focused on stand-alone systems. Recently, the Ministry of Commerce, Industry and Energy (MOCIE) officially announced the "Basic Plan for Renewable Energy Technology Development and Dissemination." This new plan aims at developing the relevant PV technology for residential rooftop systems and mobilizing a multitude of initiatives to create markets and expand market size.

NATIONAL PROGRAMME

The fundamental aim of the R&D programme is to utilize PV technology for the generation of economically competitive electric power in Korea. The main objectives of the programme are to strengthen support for research in order to bring the cost of PV-generated electricity to a competitive level, to transfer the technology to industries for commercialization and ultimately to the end users. Recent trends show that there is a transfer of leadership to the industry that is supposed to play a single role in the commercialization of the developed technologies. In particular, institutes/industry joint projects, which could provide innovative technological experiences and markets, are highly recommended. In order to accomplish these objectives, the MOCIE has given support for R&D and demonstration and has attained 2 339 million KRW and 3 900 million KRW in 2001, respectively.
These were remarkable increases compared with those in 1999, which were 1 382 million KRW for R&D and 400 million KRW for the demonstration/field test programmes. In addition, it is noteworthy that local authorities also made an important contribution to the implementation of the demonstration programmes in 2000. The local authorities matched funds corresponding to 30% of the total investment based on cost-share projects.

R&D, D

The R&D projects implemented in 2000 comprise various categories. The key projects are related to solar cells and modules. Two joint projects lead by Samsung SDI in cooperation with institutes and/or universities are valuable. One is aimed at the commercial development of multi-crystalline silicon solar cells and its application to solar-roof systems. The second one is to develop polycrystalline thin-film silicon using solution growth. The first project includes the development of inverters for distributed grid-connected systems. Apart from these projects, Samsung SDI announced, in October 2000, the achievement of 20.0% efficiency from single crystalline silicon solar cells with an area of 45.7cm^2. The somewhat basic R&D projects on thin-film solar cells have been implemented in research institutes and universities. The materials include CIGS, GaAs, amorphous silicon (a-Si), polycrystalline silicon (p-Si) and TiO2 for dye-sensitized solar cells. In the case of CIGS solar cells project lead by the KIER, various physical vapor deposition methods were studied with an objective to develop low-cost and high-efficiency solar cells. The fabrication of p-Si by Hot-wire CVD was also studied by the KIER, but its study still remains at the basic research stage. The other projects are related to cast-polycrystalline silicon, PV-thermal hybrid panel and small portable modules for electronic products. Related to R&D, on the balance of system (BOS), two projects on lead-acid battery were carried out by the Global Hightec Company. Since 1993, the MOCIE has been implementing, via the KEMCO, demonstration and field tests of various renewable energy technologies.

In addition, the Government has been encouraging and supporting local authorities to implement their own demonstration or field test projects under the framework of the "Local Energy Plan." This plan, implemented since 1997, is also meant to raise public awareness, which remains a top priority. Under the MOCIE-lead projects in 2000, five on-grid PV systems with an installed capacity of 10 to 15 kW started their operations. Under the local energy plan, two on-grid systems with a capacity of 3 and 50 kW, respectively, and four PV-diesel hybrid systems with a PV capacity in the range of 25 to 97 kW were planned for construction in 2000. In general, the Government provides 70 % of the total investment on the basis of cost-shared projects.

IMPLEMENTATION

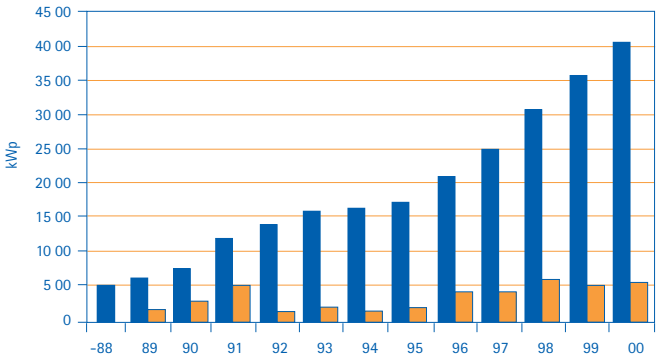
The PV market in Korea continues to be dominated by the off-grid non-domestic sector. Among various applications, the telecommunication field is the largest sector of application, followed by manned or unmanned lighthouses, highway and street lighting, tele-metering, emergency call boxes and road signaling. Recently, the share of off-

grid PV systems for aviation warning lamps on high-voltage transmission towers and CCTV for forest fire observation towers in the forest have been increasing in use. Small PV systems for sewage water purification in remote mountainous areas are attracting attention from environmental protection groups.

PV-diesel hybrid systems for remote islands and isolated houses account for a large part of the off-grid domestic market sector. These systems were essentially installed under Government demonstration or field test programmes. The total number of distributed on-grid PV systems at the end of 2000 was 19; which includes eight systems installed in 2000. These systems were installed under the demonstration and/or field test programmes. Most of the systems have PV modules installed on building roofs with supporting structures. Due to the lack of concrete promotional policies, this market sector remains undeveloped. However, there is no doubt that this sector has a huge potential and will be the largest market in the near future when various conditions are met.

The total installed capacity of PV systems in Korea was 3 960 kW at the end of 2000, and the installed capacity in 2000 was 501 kW; a 5 percent increase over the previous year (477 kW). Even though the annual installed capacity has remained at the 500 kW level during the last three years, total power almost doubled during the last five years.

Korea's PV market is still dominated by the off-grid non-domestic sector. This sector occupies 83% of the total installed power. Among 433 kW installed in 2000, the PV systems for aviation warning lamps on high-voltage transmission towers accounted for the largest market share with an installed power of more than 150 kW.
The share of the off-grid domestic sector is 8 %, but with no increase in 2000. Also in 2000, eight distributed on-grid systems with installed capacities ranging from 2 to 15 kW started their operations. This sector accounted for 9 %, as of end 2000.



Annual installed and cumulative PV Capacity in Korea

INDUSTRY STATUS

Even though one company stopped manufacturing solar cells in 2000, three companies have continued to produce PV modules: Samsung Electronics Co., LG Industrial System Co. and Haesung Solar Co. In 2000, the total production capacity was 2 000 kW, and the total production volume was 650 kW. In the previous year, two companies had a production capacity of 1 500 kW and produced 500 kW. It is worthy to note that Samsung Electronics Co. doubled its production capacity in 2000.

Samsung Electronics Co. manufactures five types of modules with a peak output of 50 to 120 W using mc-Si solar cells imported from BP Solarex. The newly developed module with a rated peak output of 120 W has a dimension of 1 128 L x 990 W x 50 mm D, and a structure glass/EVA/solar cells/EVA/tedlar. LG Industrial Systems produces various types of PV modules with a peak output power ranging from 43 to 100 W. In 2000, this company imported sc-Si solar cells from Siemens Solar Industries in USA. The module has a typical glass/EVA/solar cells/EVA/back sheet structure, which is similar to that of Samsung Electronics Company. Haesung Solar manufactures small PV modules with an output power ranging from 1 to 50 W. This company used solar cells purchased from LG Siltron Co. in the previous year. The module manufacturing process is also similar to that of the former two companies. This company is planning to produce large sizes (80 – 200 W) and color modules in the near future.

PV module prices in 2000 were varied; ranging from 7 000 to 9 000 KRW/WP depending on the manufacturing company and the order volume.

Since 1998, the following companies have been manufacturing inverters for grid-connected systems: Samsung Electronics, LG Industrial Systems and Hex Power Systems Co. These companies also produce inverters for stand-alone systems. Dongmyung Electric specializes in inverters for stand-alone systems. Prices are reduced when the size increases. The price of an inverter for a stand-alone system is about 2 million KRW/kVA for a size larger than 10 kVA.

Global Hightec Company, a battery manufacturer with specific experience in PV systems, produces tubular plate stationary type lead-acid batteries. The commercial products capacity ranges from 170 Ah to 2 700 Ah.

FUTURE OUTLOOK

The focus will be aimed at the early development of 3 kWp PV system for residential houses. Relevant technologies include high-efficient crystalline silicon solar cells and modules, inverters for grid-connection, system design and standardization.

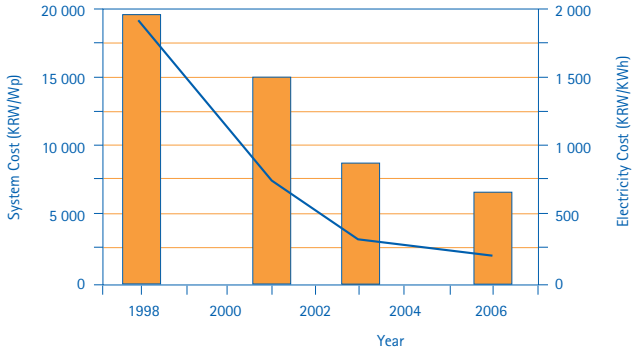
The system cost target is to reduce present 15 000 KRW/WP to 8 000 KRW/WP in 2003, and to 6 000 KRW/WP in 2006. The electricity generation cost is to be lowered to 410 KRW/kWh in 2003, and to 310 KRW/kWh in 2006 from present 700 KRW/kWh.

In addition, there are plans to install 10 000 rooftop PV systems with an average capacity of 3 kWp for residential houses during the period 2002-2006.

In order to assure successful implementation, various initiatives will be taken. First of all, in 2003, two-thirds of the initial investment cost will be subsidized. From 2004, low-interest loans will be provided instead of subsidies and the generated electricity will be purchased at a preferential tariff of 400 KRW/kWh. The difference between the electricity's purchasing price and selling price will be evenly charged to all electricity consumers by raising the electricity tariff.

Apart from these measures, the Government will require that Government organizations, local authorities and public schools supply a certain part of their own electricity needs by utilizing PV systems or other renewable electricity generation technologies.

The Government is also well aware of the important necessity for standards and regulations in the construction, grid-connection and operation of rooftop PV systems. These issues will be treated in parallel with PV field-tests and performance evaluation projects.



Cost targets of PV systems and solar electricity

MEXICO

PV TECHNOLOGY STATUS AND PROSPECTS IN MEXICO
JAIME AGREDANO, J HUACUZ VILLAMAR
ELECTRICAL RESEARCH INSTITUTE (IIE)

GENERAL FRAMEWORK

Good sunshine availability throughout the year makes the use of PV systems an attractive option for remote power supply as well as grid-connected applications in Mexico. Solar home systems, small water pumps and a variety of professional applications, mostly for telecommunications, have been installed for more than a decade in this country. A few small pilot grid connected systems have also been installed.

NATIONAL PROGRAMME

Still no national PV programme has been instrumented by the central government. Nevertheless, more than 500 kW of SHS were installed during 2001, through poverty alleviation programmes operated by municipal authorities.

RESEARCH AND DEVELOPMENT

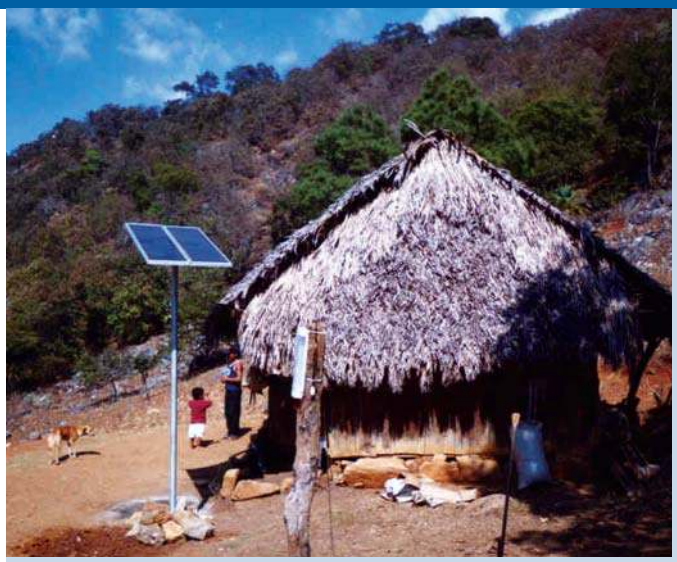
Grid-Connected PV R&D activities continued during 2001. Installed pilot systems for peak power sharing in the city of Mexicali, were monitored to determine the system's performance. Another pilot 1.7 kW system was installed in the city of Hermosillo, in northwest Mexico, for the same purpose.

PV-wind hybrids research continued during 2001. Strategies for system control were tested in connection with productive activities to foster the use of this technology in rural areas.

A pilot PV rural electrification project involving the use of nickel-metal-hydride batteries was carried out in a mountain village in the southern state of Oaxaca. Some of the systems involved were instrumented for battery evaluation purposes.

INDUSTRY STATUS

Mexican industry is manufacturing almost all BOS components for PV small off-grid installations. High capacity inverters for both grid-connected and off-grid applications are been imported as well as some battery banks for professional installations.



Solar Home Systems in rural areas

MARKET DEVELOPMENT

The Mexican PV market for 2001 was 1 043 kW, with the following segmentation: Rural Electrification 521 kW, Telecommunications 313 kW, Offshore oil platforms 104 kW, water pumping and cathodic protection 52 kW . Cumulative PV installations in Mexico by the end of 2001 were close to 13 MWp.

FUTURE OUTLOOK

In the National Energy Programme 2001 – 2006, the Federal Government has declared renewable energy of national interest. Policy actions are being instrumented to encourage private sector participation in new renewable energy projects and to expand the scope of previous programmes such as PV rural electrification.

Solar Roofs in Mexicali City

THE NETHERLANDS

PV TECHNOLOGY STATUS AND PROSPECTS
MICHIEL VAN SCHALKWIJK (ECOFYS)

GENERAL FRAMEWORK

In the Netherlands, 2001 was one of the most turbulent years for PV ever. The general framework changed completely in comparison to the years before, yielding many opportunities for PV in the long run, but also some short term frustrations.

A number of changes were put through at the same time. Following a re-orientation by the Ministry of Economic Affairs on its Renewable Energy budgets, it was concluded that RE research programmes should be more targeted towards market initiatives rather than initiated by governmental targets. As a result, option-specific programmes were ended and combined in a new Renewable Energy Programme (DEN 2001), in which projects on all different RE-options are to compete in a tender-like structure on price/performance regarding the effect of projects on the 2020 renewable energy production goal of the Ministry of Economic Affairs. Especially for PV, this seemed to be a major setback, anticipating the poor chances that a relatively low contribution in renewable energy production compared to what wind-energy and biomass would yield. However, after the first round that ended in August 2001, it appeared that one-third of the available 9 mio EUR had gone to PV research-projects. The second round ended in December.
Starting from January 1, 2001, PV together with Solar Domestic Hot Water (SDHW)-systems and heat-pump boilers were added to the list of products of the Energy Premium Regulation (EPR). This EPR is meant for house owners (including housing corporations) who invest in improving their houses energy-wise. The amount of subsidy for PV was 3.40 EUR /Wp, which could be obtained by filling in a simple form with a copy of the receipt. The subsidy can even be increased by 25% when an EPA, an Energy Performance Assessment, of the house is done.
The EPR regulation, being designed as an end user subsidy for existing houses, had some limitations. The first was solved immediately: renewable energy options could also be subsidised for new houses. The second one was more difficult to solve. The subsidy is basically a return of ecotax, so only parties who pay an ecotax are entitled to receive subsidy when applying measures from the EPR. Due to this fact the most important market segment in the NOZ-PV programme, property developers, were not able to use the EPR properly, which has now led to activities at the Ministry of Economic Affairs to develop a special scheme for this particular group in 2002.

As said, this sudden change in policy led to turbulence amongst the Dutch PV parties who joined in the so-called PV-Manifesto group, demanding consistency in government PV policy and transparent subsidy schemes. The amount of subsidy they requested was 4.5 EUR/Wp for every PV system (not only house-owners) plus a feed-in tariff of 0,23 EUR/kWh, specifically looking at the German neighbours, where the Renewable Energy Law with the 0,50 EUR/kWh for PV energy, boosted the PV market enormously. The Ministry of Economic Affairs thought this was more than they should offer, already having the EPR and DEN2001, and decided not to enforce the covenant again. To underline this decision, they pointed at the relatively low potential for PV as a contributor to national renewable energy production targets in comparison to wind-energy and biomass.

Fig. 1 - Annen zonnecentrale
The PV installation of Essent in Annen, 180 kWp is the first utilityside PV generator in The Netherlands. (Copyright Essent)

Since 2002, the Dutch PV market has come into quieter waters again. The EPR is set to 3.50 EUR/Wp for 2002, two tenders are going to be published within the Renewable Energy Programme with a total budget of 18 million EUR in which PV can play an important role and the PV-manifesto group seems to evolve into a mature branch organisation. The Ministry of Economic Affairs have now agreed that renewable energy options 'behind the electricity meter' can contribute significantly to the production goals of 2020.

Utilities like NUON and Eneco Energie have published subsidies of around 1 EUR/Wp in their service area, showing the importance of the image of solar energy in the liberalised green energy market. Furthermore, there still is wide support from environmental organisations like Greenpeace and WWF. The latter are involved in setting up a certificate for solar dwellings (for buildings that use two of three solar options: PV, SDHW or passive solar energy), of which at least 1 500 will be built in the coming years.

With all these end-user-oriented subsidies PV parties are now restructuring in order to enter the consumer market. They will have to look at the development of the German market, where, despite the broad applicability of their support scheme, 89% of the PV volume is sold to private consumers!

NATIONAL PROGRAMME

The National Photovoltaics Programme (NOZ-PV) that ran from 1997-2000 was extended to June 30, 2001, due to the publication in November 2000 for PV systems larger than 0,5 MWp. The extension included large PV systems and demonstration projects of PV in the built environment.

Fig. 2 - ECN facade and glass roof
ECN combined different techniques at their offices in Petten, partly new and partly renovation. The facade, staircase and the roof designed by Tjerk Reijenga (BEAR architects) offer space to approximately 70 kWp of PV. (Copyright Novem/Hans Pattist)

In July 2001, the Renewable Energy Programme 2001 was published which had two calls open in the course of the year, one ending on August 24th, the other on December 28th, each with a total budget of 9 mio EUR. The results of the latter one are not known to date. Of the first call, one-third of the budget was granted to PV projects.

The targets for PV are still set at an equivalent of 10 PJ primary energy in 2020, approximately 1 500 MWp. This has to be filled in by segments that market parties assume to be the most promising. No specific technology preferences (cell-technology, building integrated or not) are given.

For house-owners (including housing corporations), a subsidy of 3.40 EUR/Wp was available within the Energy Premium Regulation (EPR) in 2001, which can be increased by 25% when an Energy Performance Assessment (EPA) is carried out.

In 2002, this will be 3.50 EUR/Wp. The size of the system is not limited, with the provision that systems larger than 600 Wp have to be commissioned by an approved installer. Systems smaller than 600 Wp can be plugged into a standard socket.

RESEARCH AND DEVELOPMENT

Solar cell research in the Netherlands is mainly concentrating on improving multi crystalline and amorphous silicon production. Research on multi crystalline silicon is concentrated on metallization, passivation and texturing in order to improve the efficiency of the solar cells. New texturing and passivation technology has been proven on lab-scale and R&D is now focussed on industrial implementation. Dutch parties and European partners are jointly working on silicon feedstock in order to obtain a sustainable supply of silicon wafers. The main research parties are ECN, TU-Delft (DIMES), TNO and the Universities of Utrecht, Groningen and Eindhoven.
Amorphous silicon still is the most promising thin-film candidate for industrial up-scaling in the coming five to ten years. Akzo Nobel and Shell Solar have joined their competencies in an effort to accelerate the project for an high speed large area production facility for amorphous silicon PV. A newcomer in the thin-film business is Scheuten Solar Systems. They are investigating the possibilities for a thin-film production line.
One of the major advantages of the new Renewable Energy programme is that other technologies that had less priority in the NOZ-PV programme have an opportunity to grow. Examples are projects for organic and CIS solar cells that have recently started with subsidy from the Renewable Energy programme.

The short term changes in the governmental policy for photovoltaics have certainly influenced those research projects that have short lead times, like the development of inverters and PV building products. Existing products were improved, for instance to fit the demands of the German market, existing projects continued, but no new initiatives were started for these products.
It is expected that in the course of 2002 the developmental activities will be taken up again.
Meanwhile, PV and solar thermal building industries have come to an agreement on a National Code of Practice (NPR 7250), in which the National Building Act is applied to the constructional aspects of PV and solar thermal systems showing examples with proven constructions. Furthermore national codes were written for the electrical installation and commissioning.

Fig.3 - Floriade
At the Floriade 2002 exhibition NUON built the largest roof integrated PV system of the world. 28 000 m² of transparent PV panels yield 2,3 MWp of installed PV power. (Copyright NUON)

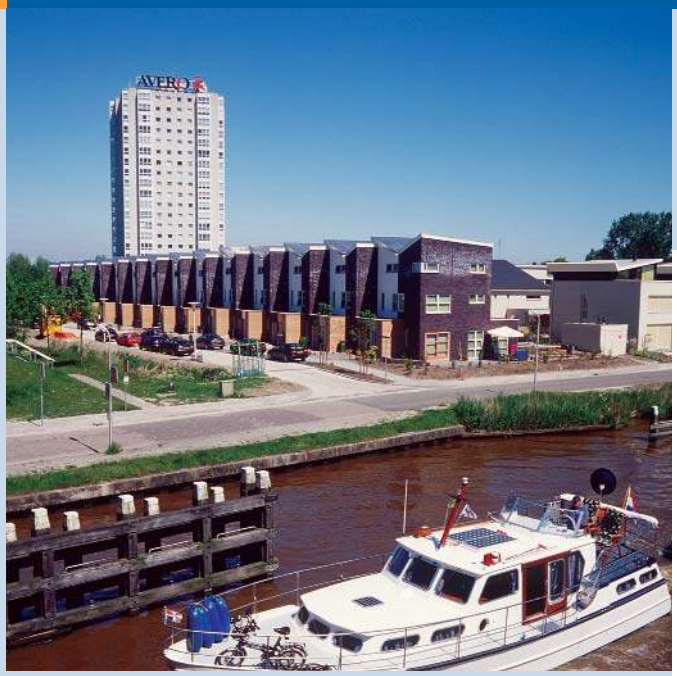


Fig. 4 - Pieter Christiaan Park
In the city of Leeuwarden 15 houses are realised according to the C02 balance concept. The heat demand of the houses is already very low so the CO2 neutrality can be achieved by generating electricity with 34 m2 PV per house. (Copyright Novem/Hans Pattist)

INDUSTRY STATUS

The merger of Shell Solar with Siemens Solar has laid the focus of Shell Solar more towards Germany. Contrary to expectations, Shell Solar has not expanded their production facility in The Netherlands.
The inverter manufacturers in the Netherlands are NKF – now part of Draka, Philips, Mastervolt, Exendis – De Drie Electronics and Victron. Mastervolt and NKF finished their new products. Philips finalised their 300 W PV inverter and will actively be in business selling PV systems from April 1st 2002. Also De Drie Electronics came on the market with their 250 W inverter under the name Exendis.
Two important newcomers are entering the PV market: Corus is developing a mounting system for crystalline panels on their aluminium roofing product KalZip. Scheuten Solar Systems is already exploring the PV market by selling turn-key PV systems. Laura Starroof, who just finished the development of an amorphous silicon on steel roofing product, went out of business.

DEMONSTRATION PROJECTS, IMPLEMENTATION AND MARKET DEVELOPMENT

Demonstration projects in 2001 were still benefiting from the funding from the NOZ-PV programme. NUON realised the world largest roof integrated PV system at the Floriade 2002 exhibition near Amsterdam Airport, totalling 2.3 MWp of semitransparent photovoltaic panels.
In the City of the Sun, where 5 MWp are planned, the first large (700 kWp) project was finished at a price of less than 4.5 EUR/Wp, and several other projects were commissioned as well. The installed PV volume in this project is currently over 1 MWp. The total of 5 MWp is expected to be reached end of 2004.
Many other attractive and innovative demonstration projects were completed in 2001. They can be seen on two websites that were also produced in 2001: www.pvdatabase.com (of IEA PVPS Task7) and www.pvinfo.nl (in Dutch – by Novem).

A boost was given to the market of small PV systems (< 600 Wp) for households, by the temporarily stackable subsidies from the NOZ-PV programme and the EPR. The project that benefited most was the Sunpower project, carried out by several utilities. Combining these subsidies plus specific utility subsidies, systems were offered for a net price less than 1 EUR/Wp (after tax). Although the numbers are not yet known, it is expected that this led to sales of somewhere between 1 and 2 MWp. The dark side was of course that system houses that could not stack subsidies were having problems to compete with these prices – one of the reasons for the PV manifesto. The stacking possibility was ended in the last quarter of 2001, with an addendum to the EPR.
Notwithstanding that, a couple of companies still managed to achieve a considerable market share in selling small PV systems in the consumer market: Buro Wilders, Stroomwerk, with their Solar Service Buro, and Ecostream, with the Beldezon concept.
It is expected that in 2002 these companies will see a vast growth, being prepared for the consumer market.

Informative links to lists of system suppliers are:
http://www.pde.nl/de/pv/adreslijst_netgekop.html
(grid-connected PV);
http://www.pde.nl/de/pv/adreslijst_autonoom.html
(autonomous PV).

FUTURE OUTLOOK

The market for PV in 2002 will become increasingly focused on the consumer market. With the introduction of the Euro, the EPR has even been increased to around 3.50 EUR/Wp. In addition, the EPA for existing houses and utility subsidies can increase the available subsidies to a mere 4.50 – 5 EUR/Wp. As a renewable energy option, its value is mainly seen "behind the electricity meter," since private households pay the highest energy tariffs. It is expected that municipalities will become increasingly involved.
Developing the consumer market will specifically require attention to quality control, education and training and improvement of the supply chain. It is expected that activities in these fields will expand during 2002.
On the other hand, systems on commercial buildings will still have a place in the PV market because of the green image that the blue panels beam out. Several utilities donate or subsidise PV systems in exchange for a long term green energy contract. A number of PV systems for commercial buildings are still in preparation as part of the former NOZ-PV programme.
Another interesting option with a lot of potential is shown in one of the NOZ-PV projects: the municipality of Waalwijk and REMU are partners in a project in which 0.8 MWp of PV panels are placed in combination with wind turbines on a land-fill area. The wind turbines make the total project financially feasible. Moreover, the PV system decreases the special planning problems for the wind turbines because of their image.

The Renewable Energy programme 2002 will have three calls of 9 mio EUR each during 2002. Looking at the results of 2001, it is expected that PV research projects will use about one-third of the budget for a vast spectrum of research topics, from improving the production processes of multi crystalline silicon to exploring newer cell technologies like CIS and organic cells.

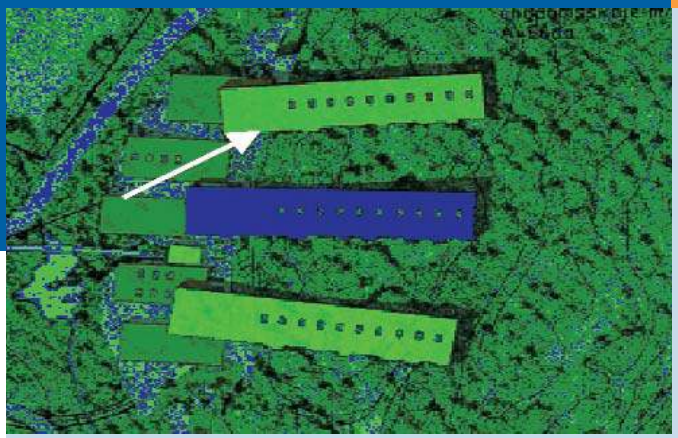
It is expected that in the course of 2002 a subsidy scheme will become available for property developers to increase their possibilities of integrating renewable energy options in new houses, which will renew their interests in this technology.

All in all, the PV market will be maturing in 2002, with the establishment of a professional branch organisation and the growth of business-to-consumer sales. Solar energy remains an attractive green energy option in many ways: solar sells!

Fig. 5 - Lagune Mayersloot-West)
Houses in the Lagune project in Langedijk, which form part of the 5 MWp City of the Sun. The houses have systems varying in size between 3 and 8 kWp, adding up to a total of 130 kWp. Because of smart organisation and system design, system prices were achieved of below 5 EUR/Wp (excl of VAT).
(Copyright Novem/Hans Pattist)

NORWAY

PV TECHNOLOGY STATUS AND PROSPECTS
KNUT-ERIK MADSEN



Sketch of Kvernberget Junior High School

GENERAL FRAMEWORK

Renewable sources of energy are an essential ingredient of the Government's plan for energy production in Norway for the future. The political willingness to support PV in general is still limited. The public financial support is concentrated on development of basic materials and production processes for PV. The upcoming feedstock problem for the PV industry and the strong metallurgical silicon industry in Norway, make it natural to take on R&D in this area.

The enormous natural gas resources in the North Sea are not used onshore in Norway. A new directorate called ENOVA, is responsible for the reorganisation of the energy use from direct electric heating to natural gas and central heating. ENOVA is also responsible for financing and demonstrating how renewables can take part in the whole energy picture of Norway.

In the Spring of 2002, the Government will set forth a notification about natural gas and trade of "green certificates." This will probably send new signals out to the energy market and help to promote none polluting energy.

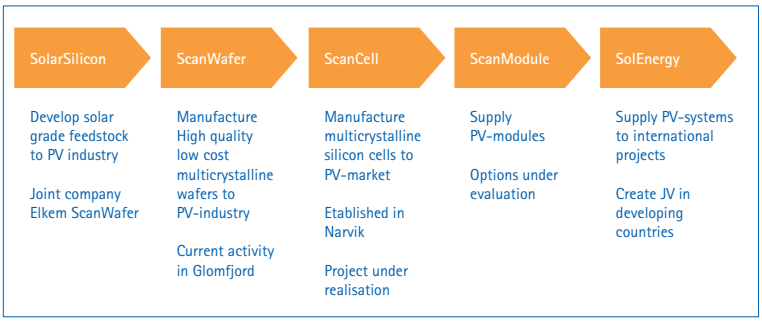
A new solar cell laboratory at IFE with a production line for crystalline silicon solar cells was opened in desember 2001 by managing director Bruno Ceccaroli from ScanCell AS (Task 1 member) (left). Department head for energy systems Per Finden (right) and section head for renewable energy Arve Holt (Task 3 member) (middle) are also present.

An interesting initiative that perhaps will awaken the Norwegian politicians, is the EU project "PV Nord":
In order to reach the goals of the EU White Paper on Energy (12% renewable energy before 2010), building integrated PV-modules is one of the possible measures to take. The EU wishes to reinforce the development of building integrated systems in all European countries. PV-Nord is a tool in this context that especially focuses on the northern part of the EU and the accession states. The project was started in January 2002 and will continue until the end of 2004. It consists of eight demonstration projects and thematic work in the following areas:

- Aesthetics and building integration
- Environmental aspects
- Power production
- Management and information and control technologies (ICT)
- Financing and ownership

The project is co-ordinated by the NCC Construction Company in Sweden and consists of partners from Sweden, Denmark, Finland, Norway and the Netherlands. KanEnergi (www.kanenergi.no), a Norwegian consulting company, is responsible for the work on financing and ownership.
A project website will be established for further and continuously updated information on the project. Please visit www.ncc.se for the future internet reference.

Fig. 1 From Silicon feedstock to Solar Energy Systems



NATIONAL PROGRAMME

The NYTEK programme financed by the Norwegian Research Council ended in 2001. The programme was renewed for another 5-year period, but the Photovoltaics in this programme must compete with other renewables like bioenergy, wind, waves, hydrogen, thermal solar and others.
New renewables (except hydro) are exempted from a certain energy tax, but still, there are no market incentives for promoting photovoltaic systems. Photovoltaics are looked at as other renewables. In a very windy country which has such a long, dark winter, photovoltaics are not always in the winning position amongst renewables.

RESEARCH AND DEVELOPMENT

The funding of R&D for photovoltaics is still at a low level in spite of the growing industrial activity on photovoltaics.

A new R&D solar cell laboratory has been established in Norway. Last summer, the Institute for Energy Technologies (IFE) invested in a R&D production line for crystalline silicon solar cells. The line typically produces batches of 25 – 50 solar cells given a certain parameter set-up. Currently, the production line produces solar cells with an efficiency of around 13-14 %, based on a standard process delivered by the equipment.

This new laboratory is a part of the strategic programme in the area of renewable energy at the Institute. IFE's long-term goal is to build up national and international expertise on production of solar cells based on crystalline silicon. To achieve this goal IFE will:

- Strengthen the knowledge base concerning the formation of different layers in a crystalline silicon solar cell. By doing this, IFE will be in the position to optimise the different sub processes and develop new ideas to increase performances for both national and international customers.
- Establish a national characterization laboratory for silicon based solar cells. Producers of solar cells, wafers and solar grade silicon will then be able to test their products. In this laboratory, our customers may also obtain information about the efficiency, impurity levels, homogeneity, and electrical properties of their products.
- Educate students on both the Master's and PhD level as well as arrange courses for and training of industry personnel.

The Norwegian Technical University of Trondheim (NTNU) has a programme (http://www.chembio.ntnu.no/users/hagen/solceller/index.html) financed by the Norwegian Research Council and Industry called: "From Sand to Solar Cells." The programme has several projects. Some examples from the programme:

- Feedstock for Solar Grade Silicon: Development (patenting) of a new electrochemical process for producing solar grade silicon. The project will be of importance for solving the feedstock problem (availability of low cost solar grade silicon) in the silicon based solar cell industry. (Espen.Olsen@matek.sintef.no).
- Directional Solidification of Multicrystalline Silicon: Advanced equipment has been installed at NTNU/SINTEF for studying directional solidification of silicon. The research project will provide information about optimisation of process parameters for making multicrystalline silicon ingots for the solar cell industry; characterization of crystal properties, distribution of impurities in crystals and along grain boundaries. The project is important for determining acceptable impurity limits in solar grade silicon wafers and for the improvement of wafer materials. (Lars.Arnberg@matek.sintef.no and Otto.Lohne@matek.sintef.no).

IMPLEMENTATION

There are no new initiatives from the government focusing on photovoltaics.

On the local level, some initiatives have been taken. One example is a demonstration of PV cells on Kvernberget Junior High School in Fredrikstad, Norway. (front page)
Kvernberget Junior High School has a green section that will demonstrate growth, trees and plants, and recycling of materials. There is a blue section that will demonstrate water, and a yellow section that will demonstrate the sun and solar energy. The plan is to use small string inverters which require the connection of 12 standard modules in series. It means that the system will work at 216 Vdc and it will inject into the grid at 240 Vac. The school wants PV cells in laminated glass, the yellow polycrystalline type.

In Oslo, a new section of town will be built over the next years. It will include offices, an opera house and 5 000 apartments (900 000m2). The goal of the local authorities is to have balance between production and consumption of energy within the area. This is a difficult task and from E-CO Partner (consultant www.e-co.no), it has been suggested to use photovoltaics to produce electricity. It will be necessary to use 150 000 m2 of PV-panels to produce a sufficient amount of electricity.

INDUSTRY AND COMPETENCE

An emerging Norwegian PV industry is clustering around "ScanWafer." (fig. 1) "ScanWafer" is expanding and has finished a new production facility at Glomfjord and has decided to build a new production facility at Herøya/South of Oslo. "ScanCell" will operate during 2002. "SolEnergy" is operating in South Africa.

Architects and consultants are exporting competence to several areas. Here are some interesting examples:
SunLab Architects (sunlab@c2i.net) has designed a solar TV building in Colombo for WGM Ltd, Sri Lanka (www.sunlab.no). It is an environmentally friendly building with a grid connected solar PV system. The Media Centre in the capital Colombo incorporates a 25kW panel array, electrically arranged in 3kW blocks, each with its own inverter to provide 240V ac from the 12V dc panels. There are plans for expanding the system to 100 kW.

Colombo TV Building

An example of a health centre building with the panels for the lighting and vaccine refrigeration systems on the roof. The installation on this building is aesthetically pleasing.

The solar array is an integral part of the whole building, with its floor area of almost 3 000m^2 that is designed to have the minimum possible impact on the environment. It uses natural methods of ventilation, cooling and lighting, which together keep electrical demands as low as possible.
Natural paints to improve indoor climate (sick building syndrome), complete handling of human waste on site and a recycling plant for waste water are other components of the design.

The solar modules provide protection and/or shade as appropriate. The whole system was tendered for and the international tender competition was won by Engcotec of Stuttgart, Germany. They supplied a turnkey contract including Italian solar modules.

KanEnergi (www.kanenergi.no) has assisted the Ministry of Health in Mozambique in a project called "Solar Energy for Rural Health Facilities." They are defining needs and priorities with regard to electricity use, preparation of tender documents, negotiation of contract, monitoring of installation work, and general follow-up. In addition, KanEnergi has performed a review of the institutional set-up for maintenance of the systems.
The Project consists of solar electrification of approximately 150 rural health facilities nationwide.

MARKET DEVELOPMENT

The main markets for PV in Norway have been related to off-grid applications: This applies to cabins, leisure boats and lighthouses/lanterns along the coast. Exceptions are the demonstration projects for which grid-connection, in some cases, were suitable. However, in the period after 1992, the slowdown in the market for cabins has partly been compensated by the development of new markets. The most significant markets are PV powered coastal lighthouses. Even north of 70o, PV, provided that the battery package has sufficient capacity, may power lighthouses. Approximately 2 350 installations serving lighthouses and coastal lanterns have been realized. The smallest are equipped with one single module of 60 W and the largest with arrays counting up to 66 modules.
Applications of stand-alone PV for telecommunication stations and for leisure boats have also grown over the past years.
In the period after 1992, application of PV in combination with other energy sources has been demonstrated for permanent domestic dwellings where the distance to existing electricity grid exceeds approx. 10 km. In particular, combinations of PV with diesel generators have been used. Utility companies have made some selective investments for providing electricity to remote dwellings. The total cumulative PV Power for each submarket is shown in Table 1.

TABLE 1

sub-market application	31. Dec. 1992 kW	31. Dec. 1993 kW	31. Dec. 1994 kW	31. Dec. 1995 kW	31. Dec. 1996 kW	31. Dec. 1997 kW	31. Dec. 1998 kW	31. Dec. 1999 kW	31. Dec. 2000 kW
off-grid domestic	3 700	3 970	4 240	4 460	4 680	4 900	5 100	5 400	5 650
off-grid non-domestic	100	130	160	190	220	250	300	320	330
on-grid distributed							4	6	50
on-grid centralised									
TOTAL	3 800	4 100	4 400	4 650	4 900	5 150	5 400	5 730	6 030

The solar Butterfly

NICHE MARKETS

SunLab owner, Civil Architect Harald N. Røstvik and the Industrial Designer, Peter Opsvik have designed and constructed a prototype three-wheeler, "THE SOLAR BUTTERFLY," a solar electric vehicle for Asian conditions. The vehicle has been undergoing extensive tests in an Asian garden city (no motorways) and the results of tests on almost rural-like roads with slow traffic are encouraging.

The NiCad battery bank is fed by 340Wp solar modules and can also be charged from the mains. A windmill in combination with the solar PV has also been tried out.

The initiative has two objectives:

- The signalling effect/debate
- Technological development

Further technological development of The Butterfly, by constructing more and improved prototypes, will depend on external financing. More information can be found on www.sunlab.no

FUTURE OUTLOOK

The most interesting trend in Norway for PV developments is the emergence of the PV industry taking advantage of national competence and resources. ScanWafer (fig. 1) will be one of the world's largest manufacturers of multicrystaline silicon wafers within a few years.

Currently, the solar power industry depends on a semiconductor industry silicon by-product for the production of solar cells, the core component in systems that generate solar electric power. The limited availability and high price of solar-grade silicon feedstock have historically constrained solar industry growth. Developing a dedicated source of low-cost solar-grade silicon feedstock is key to removal of this fundamental barrier to widespread adoption of solar electric power and further growth in the solar industry. At present, several global industrial players are working on resolving the feedstock issue. In Norway, Elkem is developing its metallurgical process technologies to industrialise an efficient process for production of solar grade silicon in co-operation with AstroPower.

Elkem is the world's largest producer of silicon metal. The programme where Elkem and Norwegian Technical University are involved is addressing perhaps the most critical issue for the global PV industry, the emerging lack of sufficient feedstock for PV.

PORTUGAL

PV TECHNOLOGY STATUS AND PROSPECTS
PEDRO SASSETTI PAES, MINISTRY OF THE ECONOMY

Normalised stand-alone systems for rural electrification in Portugal.

GENERAL FRAMEWORK

It is well known that Portugal has no fossil fuel energy sources, importing more than 85% of its primary energy consumption (the remainder are endogenous hydropower and biomass). Moreover, the GDP energy intensity is the highest among the European Union Member States and still growing, reflecting the lack of efficiency of the Portuguese energy system.

In 2001, the government launched a new energy policy instrument - the E4 Programme (Energy Efficiency and Endogenous Energies), consisting of a set of multiple, diversified measures aimed at promoting a consistent and integrated approach to energy supply and demand. By promoting energy efficiency and the use of endogenous energy sources, the programme seeks to upgrade the competitiveness of the Portuguese economy and to modernise the country's social fabric, while simultaneously preserving the standards of living of future generations by reducing gas emissions, especially the CO2 responsible for climatic change.

Aiming at simultaneously assuring the security of supply, reducing the energy bill and preserving the environment, the E4 strategy relies upon three main lines of action:

- Diversifying the access to energy sources available in the market and increasing the security of services provided by energy suppliers;
- Promoting the improvement of energy efficiency, thereby contributing to reduce GDP energy intensity and the external energy bill, on the one hand, and responding to climate change, on the other hand, laying special emphasis on the opportunities and means of optimising demand-side efficiency;
- Promoting the use of endogenous energy sources, namely hydro, wind, biomass, solar (both thermal and photovoltaics) and waves, establishing a highly dynamic compromise between technical and economic viability and environmental constraints.

While in the past 5 years, the main priorities were focused on the introduction of natural gas (aiming at progressively substituting oil and coal in the energy balance) and liberalization of the energy market (by opening this former state-owned sector to competition and private investment), the emphasis for the next ten years will be put on energy efficiency (supply and demand sides) and exploitation of endogenous (renewable) energy.

NATIONAL PROGRAMME

For the first time, goals concerning the exploitation of renewable energy sources (RES) for power (and thermal) generation have been established by the E4 Programme. These goals take into account the EC energy framework, namely the RES Electricity Directive (2001/77/CE), according to which the indicative figure for Portugal's target for renewable electricity, expressed as a percentage of the gross electricity consumption by 2010, is 39% (including large hydro).

The goals established by the E4 Programme for 2010 are:

- 4 400 MW additional installed power from renewables (doubling the current capacity), of which are wind - 3 000 MW; small and large hydro - 1 000 MW; others - 400 MW (biomass & waste – 300 MW; wave – 50 MW; PV – 50 MW).
- 500 MW additional CHP (currently 1 200 MW).
- Solar thermal: ~1 million m2 (currently 200 000 m2), based on a sustainable annual market of 150 000 m2 (currently ~5 000 m2).

A set of initiatives (legislation, incentive schemes) had been introduced by the end of 2001, aiming at stimulating the market (private investors), not only for RES electricity, but also in the field of CHP and solar thermal applications, namely:

- Decree-Law defining the conditions regulating the awarding and management of grid interconnection points for Independent Power Producers.
- Decree-Law altering the price of renewable electricity sold by independent power producers to the public grid.
- Decree-Law revising the technical and tariff conditions regulating the combined heat and power (CHP) generation.
- Launching a national programme for supporting wide diffusion of solar water heating.
- Adapting or broadening the scope of financial incentives for energy efficiency and use of endogenous energies in the framework of the POE Programme (Operational Programme for Economical Development).

RESEARCH, DEVELOPMENT AND DEMONSTRATION

PV R&D activities are carried out by Universities and National Laboratories (e.g., INETI) and mainly address amorphous and thin film crystalline silicon technologies.

Applied research, demonstration, dissemination and other activities such as development of modelling and sizing methods, involve Public Research Laboratories (INETI), Energy Agencies (ADENE and regional agencies), Universities and utilities. Demonstration systems concern mainly remote electrification and professional system applications (TV and telephone repeaters, parking meters, water pumping), as well as some of the few grid-connected systems.

IMPLEMENTATION

One of the most significant initiatives in 2001 was the "Renewable Energy Forum", carried out in 2001 by a group of experts in the different RES domains, under the co-ordination of INETI and DGE (government's Directorate General for Energy). The Forum performed a portrait of each RES, identifying current use, in-country potential and barriers, and proposed measures to overcome these barriers and deepen their exploitation, thus providing a significant contribution to the E4 Programme, as far as renewables were concerned.

Among the government initiatives introduced in the framework of the E4 Programme, the new (revised) legislation promoting renewable electricity deserves special emphasis: the tariff rates are now differentiated by technology, allowing not only for increasing penetration of consolidated technologies (wind, mini-hydro), but also for developing projects relying on emerging technologies with high potential in the medium run (e.g. biomass, wave and photovoltaics). In particular, the new buy-back rates for PV are 0,28 EUR/kWh (P> 5 kWp) and 0,50 EUR/kWp (P< 5 kWp), which are considerably higher than the former tariff (0,06 EUR/kWh).

Financial incentives for renewables and energy efficiency applications are available under the POE programme (2000-2006) – III EC Framework Programme. Grants are provided on the basis of energy and environmental value of the projects, typically ranging from 20% to 40% of the total eligible costs. The total indicative budget for renewables and co-generation projects is 350 mio EUR for the whole period (2000-2006).

INSTALLED POWER IN PORTUGAL (1990-2001)

Year	Stand-alone (kWp)	Grid-connected (kWp)	Total annual power power (kWp)	Cumulative power (kWp)
1990	55		55	79
1991	43		43	122
1992	47		47	169
1993	40	10	50	219
1994	40		40	259
1995	75	2	77	336
1996	88		88	424
1997	98	5	103	527
1998	100	21	121	648
1999	100	146	246	894
2000	142	33	175	1 069
2001	128	51	179	1 248
Total by end 2001	980	268	1 248	
%	79%	21%		

Other indirect market development incentives for renewables consist in reduction of VAT rate from 17% to 5% on renewable equipment, custom duties exemption and income tax reductions.

Non government institutions and private companies have also been involved in PV implementation:

- the national Agency for Energy (ADENE) is developing a considerable effort in promoting PV installations, especially in isolated, non grid-connected rural communities.
- The largest Portuguese electrical utility (EDP) participated in a number of PV projects, as part of its R&D activities on New Energy Technologies, including participation in international networks (e.g., EURELECTRIC, EURE) or co-operation programmes (e.g., IEA PVPS) and in demonstration projects supported by the EU or ENERGIA, either in stand-alone and on-grid distributed systems.
- The BP "Sunflower Project", started in 1998 and consisting in the integration of PV modules on BP gas station canopies. So far, about 250 kWp have been installed.

INDUSTRY STATUS

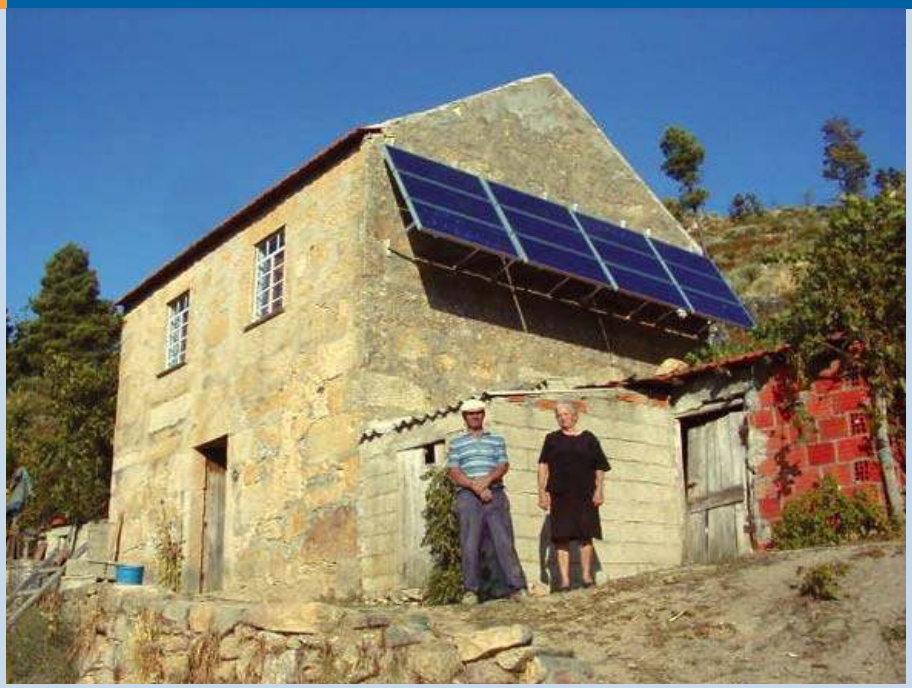
There are no PV cell manufacturers in Portugal. One company is manufacturing PV modules (cell assembling), mainly for exports. About 10 companies are supplying and installing PV modules and other system components imported from EU, USA and Japan. The manufacturing capacity in the PV sector is limited to solar type or stationary battery manufacturers (SPAT, AUTOSIL) and some small power charge regulators and appliances.

MARKET DEVELOPMENT

Although there is a lack of consistent data, in particular in the past 2-3 years, the total installed PV capacity by the end of 2001 is likely to be in the order of 1 250 kWp, of which 79% are stand-alone applications and 21% are grid-connected applications. The average annual growth in the period from 1995 to 2001 was about 25%.

FUTURE OUTLOOK

The Portuguese strategy for the promotion of renewables, introduced by the E4 Programme, will likely contribute to meet the targets agreed to under the EU Directive on the promotion of electricity from RES in the internal electricity market. As far as PV is concerned, the goal proposed by E4 corresponds to the installation of at least 50 MW in a ten year period, which means an average annual growth of more than 40%.



Normalised stand-alone systems for rural electrification in Portugal.

The opportunity exists for such a (strong) market development – favourable legal framework, tariffs and incentive schemes. However, that goal will only be reached provided a few critical barriers are overcome: PV price, equipment and installer certification, low voltage grid interconnection legislation and building codes for PV integration.

SPAIN

PV TECHNOLOGY STATUS AND PROSPECTS
JESÚS GARCÍA MARTIN & ALFONSO DE JULIÁN, IBERDROLA GENERACION
LUIS ALBERTO CALVO & ESTEFANIA REOLID, EXTERNAL COLLABORATORS

GENERAL FRAMEWORK

General framework that Renewable Energies present in Spain remains quite advantageous. The objective is to achieve a 12% (from 6% nowadays) renewable energies contribution to the energy national balance by year 2010, in line with the content of the European Union White Paper. This objective requires different measures, both at national and regional level, to be approved in order to promote the development of renewable energies.

Photovoltaic solar energy was, until recent years, one of the most unknown renewable energies. Nowadays photovoltaic energy has a very positive perception on the part of the society, thanks to the realization of singular projects, publicity campaigns, and a major presence in the media. On the other hand the solar resource in Spain is very important, so photovoltaic solar energy can help to reduce the dependence from fossil fuels and contribute to improve the environment by reducing polluting gases.

All these reasons, together with the legal obligation for the utilites of buying at an advantageous price the energy generated by photovoltaic systems connected to the grid, are promoting the advance of PV energy development. It can be shown in the amount of photovoltaic installations, mainly grid connected, which have experienced a very important growth in Spain during the last years.

NATIONAL PROGRAM

The Spanish Government has opted for renewable energies to make its contribution more important to the national energy balance. Spain's first step in promoting renewable energies was the development of the Renewable Energy Program 1991-2000, whose main objective was to increase the contribution of renewable energies to the national balance of energy. In the photovoltaic solar energy area, the objective was to increase the installed power of 2.5 MW during the Program. These figures have been easily exceeded and photovoltaic power has increased by 5 MW since the start of the Program.

In order to continue with this strategy, a new Plan for the promotion of renewable energies was approved by the Government at the end of 1999. The new Plan for the Promotion of Renewable Energy during the period 2000-2010, will serve to set a new pace for the development of these energy sources and consolidate Spanish policy on renewable energy, in line with the content of the European Union White Paper.

Concerning photovoltaic solar energy the main measures and incentives included in the new Plan are:

Public subsidies to R&D projects whose objectives are the improvement of PV technologies and the improvement of production, commercialisation and installation processes.

Public subsidies to the installation of PV systems, both off-grid and grid connected systems.

Establishment of a new regulation for the connection of PV systems to the grid.

Tax benefits for PV installations.

The implementation of this Plan has presented a first important result during the year 2000: the approval of the Royal Decree 1663/2000 which establishes the technical conditions for the connection of photovoltaic systems to the low voltage grid. This is a very important step in order to get a major penetration of photovoltaic installations into energy system.

On the other hand, the Royal Decree 2818/1998 which establishes the incentives to photovoltaic solar energy injected to the grid has not modified their contribution during the year 2000, its value remaining at 0,4 euro for installations under 5 kW and 0,2 euro for installations larger than 5 kW.

R&D AND DEMONSTRATION

Cells

The main objective of manufacturers and research centers is to reduce costs and to increase the efficiency and the reliability of photovoltaic modules to promote the competitiveness of solar PV energy in Spain.

CIEMAT

PV Modules Optimised for Building Integration - PV-MOBI
The project, co-ordinated by CIEMAT has the objective of developing new designs of PV modules for building integration applications based in the study of its optical, thermal and electrical generation characteristics. At present the final prototypes have been manufactured and are being tested.
Improvement of Photovoltaic Modules. Measure for Withstanding Electrical and Thermal Effects caused by reverse biasing of cells - IMOTHEE
The objective of IMOTHEE project is to improve the design of photovoltaic modules of different cell technologies with respect to the hot-spot safety measures for longer lifetimes and a greater system efficiency.

Study of the Degradation of PV Modules

Electrical and thermal characterisation of modules that apparently have suffered degradation. Infrared thermography techniques have been used to detect failures in PV solar modules.

IES (Institute of Solar Energy)

Crystalline silicon

A dynamic model has been developed which clarified the impurity extraction process. Thank to this method, bifacial cells have been obtained with efficiencies of 17.7% (back face) and 15.2% (front face). These are the best values recorded in the world with this material.

Thin film

IES together with Ioffe Institute have developed solar cells of GaAs with an efficiency of 26.2% to 1000X and 25% to 2000X.
Photovoltaic concentrator
Design and performance of a solar concentrator (1300X). Using AsGa cells to 1000X, IES has achieved 20% of efficiency with this system.

ISOFOTON

PV venetian store: PV module which combines bifacial and concentration cells.
PV MOBI: Big PV modules to integrate in buildings
INFLATCOM: Concentration modules (1000 X) with AsGa
HISICON: Concentration modules (200-500 X) with Si

Inverters

The main Spanish companies involved in the development of inverters for PV applications are ENERTRON and ATERSA. During this year, ENERTRON has developed inverters of 630 kW and 1 MW to work with high DC voltages. On the other hand, ATERSA has developed a digital control system for grid-connected inverters.

IMPLEMENTATION

1. "Grid connected PV plant in "Palacio de La Moncloa" - Madrid

A 40 kW grid connected PV plant has been installed in Madrid, in the gardens of the Palacio de la Moncloa, official residence of the Spanish President. This project consists of the PV integration in a special structure, where the President can receive his guests for receptions, press meetings and others uses. The technical objective of the project is to develop PV solutions adequate for the integration of PV in open areas. To achieve this goal, new modules were developed together by the three PV Spanish manufacturers with a new design based on both flat and curved surfaces. Four elements are important in this project: reliability and costs, aesthetics, technical quality and monitoring and energy.

The building integration concepts, support structure and civil works of the installation was carried out by IBERDROLA who also performed the grid-connection. Another collaborators of the project were IDAE, IES (ETSITM-UPM), CENTRO PARA LA CONSERVAÇAO DE LA ENERGÍA, ENERTRON, BP SOLAR, ISOFOTON and ATERSA. The project was supported by the EU.

2. Grid connection in the New Technologies Building

This year, ATERSA has performed the installation of a 17.28 kWp photovoltaic system connected to grid in the new technology building in Cádiz. The main goal of this project is the self supplying of some internal networks of the building and also the research and developement of this type of energy. To achieve this objective, there are an acquisition system and a monitoring system. The photovoltaic modules are located on the roof of the building as the following figure shows.

3. Photocampa

This project consists of 318 kW photovoltaic plant connected to grid in which the modules are integrated on parking-lot structures. This installation is located in Tarragona and covers an area of 5 000 m2. Also, it is researching the possibility to use this PV installations to charge batteries of hybrid or electric cars. The partners of the project are ISOFOTON, SUNWATT FRANCE, BIOHAUS, ICAEN, Newcastle PV Aplications Centre, and BERGË Y CIA owner of the campa.

Industry status

At present, there are 3 important manufacturers of photovoltaic cells and modules in Spain which are developing new technologies to improve the efficiency and cost. These manufacturers are ISOFOTON, ATERSA, BP-SOLAREX.

The technologies, which these manufacturers are developing, are mainly thin-film cells, concentration cells, and photovoltaic modules to integrate on roofs.

The production of modules and PV cells is represented in the following table:

In the scope of power conditioning systems, Spanish manufacturers are developing new equipments, mainly connected to grid, with a wide range of power.

Market development

Nowadays development of the photovoltaic market in Spain is strongly tied to the existence of subsidy and promotions programs for this type of energy. The main measures to promotion photovoltaic solar energy can be summarized as follows.

Renewable Energies Plan 2000-2010. This new Plan offers economic and regulatory measures to favour photovoltaic solar energy. Economic measures have not been defined in the new Plan yet but it is expected that new lines of public subsidies for photovoltaic installations will appear in a short period of time. According to regulatory measures the most important one is the new law which regulates the technical conditions of the connection of PV systems to the grid.

Regional Plans for the Promotion of Renewable Energy.
Besides the National Plan, several Spanish Autonomous Regions have developed specific programs to support renewable energies. Concerning photovoltaic solar energy, these programs subsidise PV installations, both off-grid and grid connected. The subsidy concerned is about 30-35% of the total installation cost.

The Royal Decree 2818/1998 provides an advantageous power rate to kWh produced by photovoltaic solar facilities connected to grid. Utilities must buy photovoltaic electricity at 0,4 EUR/kWh for systems of less than 5 kW and at 0,2 EUR/kWh for systems of more than 5 kW.

This sort of measures, together with a major knowledege and acceptance of photovoltaic energy on the part of the public, have contributed to the constant growth of photovoltaic sector in recent years. This photovoltaic market growth is reflected in the increase of new companies devoted to engineering, comercialization and installation of photovoltaic systems.

In year 2000 the total PV power installed in Spain was about 10 MW. During that year power installed experimented an increase of 12% with regard to year 1999. The major power percentage corresponds to isolated systems although grid connected systems are the ones that are experiencing a bigger development.

FUTURE OUTLOOK

Isolated PV systems present a wide range of applications perfectly defined, so its market share is stabilized. Grid-connected PV systems are those that present the best growth opportunities due to the regulatory frame existing nowadays and it is foreseeable that this sort of systems will be predominant in a few years.

Within grid connected systems innovation will be the key to change the power busines. For this reason building integration offers one of the most promising ways for the development of photovoltaic market. Photovoltaics can be installed on a wide range of surfaces and can be integrated into materials such as glazing, opening up the possibility of combining energy production with other functions of the building envelope, such as roof and facade integration.

Because of continuing price decreases, some time in the near future, whether it's 5-6, or 10-12 years, the price of photovoltaic is going to be in the competitive range against retail electricity. At that point, customers are going to have the cost-effective option, and are going to exercice that option, of choosing photovoltaic solar energy.

Despite uncertainties of this time of transition as utility systems undergo restructuring and begin to face competition, now is the time to move forward with serious grid-connected PV commercialization and to develop and implement utility PV business strategies.

The successful, accelerated commercialization of the domestic, grid-connected PV market needs to be a collaborative effort of many participants. Utilities, local agencies and different companies involved in this subject must join together.

Manufacturers need to invest now in this market development and in new production, to create a profitable market for the future.
This report has been produced with the collaboration of BP-SOLAREX, ENERTRON, ATERSA, ISOFOTON, IES, CIEMAT.

TABLE 1: MODULES MANUFACTURERS IN SPAIN

Company	Cell Production (MWp)	Production Capacity (MWp)
Atersa/Astrasolar	2	3.8
BP Solar Espa(a	7	10.0
Isofoton	6	10.0

SWEDEN

PV TECHNOLOGY STATUS AND PROSPECTS
MARIA MALMKVIST, SWEDISH ENERGY AGENCY
CRISTIAN ANDERSSON, ELFORSK- SWEDISH ELECTRICAL UTILITIES' R&D COMPANY

GENERAL FRAMEWORK

The Swedish Energy Agency is the national authority on issues regarding the supply and use of energy. Its main task is to implement the energy policy programme approved by the Swedish Parliament in the spring of 1997. The aim of the programme is to establish an ecologically as well as economically sustainable energy system. One part of this is to promote the use of renewable energy sources such as hydropower, wind power and PV.

Elforsk – the Swedish Electrical Utilities' R&D Company is owned by Swedenergy – the Swedish trade association for production, distribution and sale of electrical power and the Swedish national grid. Elforsk is to conduct efficient R&D of importance to generation, transmission, distribution and utilisation of electricity.

The Swedish electricity supply system mainly consists of nuclear and hydropower. Wind power is still a small, but growing, part of the energy system. Energy from PV is negligible. There are a few grid connected PV systems but the main volume is the domestic-off-grid sector, typically recreational applications like remote cabins, campers, caravans and boats.

Today there are no market initiatives or regular subsidies directly promoting PV in Sweden. However, the Swedish Energy Agency is involved in developing a future system for promotion of renewable energy through green certificates. The Agency also provides funding for cost-shared Research, Development & Demonstration projects as outlined below.

NATIONAL PROGRAMME

In 1996 the Swedish Energy Agency together with the Swedish Foundation for Strategic Environmental Research, MISTRA, decided to start a new and merged programme for R&D on PV. The programme is called Ångström Solar Center (ÅSC) and is located at Uppsala University. The first phase had a total financing of 70 000 000 SEK, approximately 700 000 USD , and lasted until the end of 2000. The second phase started at the beginning of 2001 and will last until the end of 2004 with a total financing of 80 000 000 SEK.

The overall goal of the Ångström Solar Center programme is to contribute to a future sustainable energy system and to the economic competitiveness of Sweden.

The approach is to start from an existing strong scientific platform and evolve progressively toward applications by scale-up, prototype manufacturing, and eventually, commercialization in three sub-programmes:

- Thin Film Solar Cells
- Smart Windows
- Nanostructured Solar Cells

Grid connected 10,9 kWp semi transparent PV-system. Apartment building in "Bo01 City of Tomorrow - a European housing exhibition," Malmö, Sweden. (Photo Carl Michael Johannesson, 2001)

Furthermore, the Swedish national co-financed programme on PV systems and applications, managed by Elforsk, is conducting its second three-year period (2000-2002). It primarily involves the energy and building industry. Architects represent new partners. This programme is complementary and to some extent linked to the Ångström Solar Center R&D programme. The main task is to perform development, objective analysis and information dissemination concerning technical issues, costs and applications of PV systems.

Installation of two roof integrated PV-systems in Hammarby Sjöstad, Stockholm (JM Byggnads AB). Total installed capacity 11,4 kWp semi transparent modules.
(photo - Jonas Hedström, Energibanken, 2001)

RESEARCH

The Ångström Solar Center R&D programme embraces three project areas as mentioned earlier. The main challenge for Phase II is to progress further along the line toward applications by scale-up, prototype manufacturing, and spin-off toward commercialization. The Thin Film Solar Cells project is technologically the one closest realization. The other projects should move along the same line. The Smart Windows project is currently ahead of the Nanostructured Solar Cells project in this respect, but the latter has interesting potential for niche applications.

The technical achievements from CIGS thin film solar cell research in Sweden include cell conversion efficiencies up to 17%, at the time making the breakthrough towards truly high performance thin film solar cells. In 2000, a sub module consisting of nine cells in series and having 16,6 % efficiency was fabricated. This is the present world record for a solar cell module of any thin film material. This has resulted from R&D efforts where the focus has been on CIGS film fabrication by co-evaporation. A large area deposition concept, suitable for mass fabrication, has been invented and patented. Performance and cost goals shall be achieved by utilising processes and materials that minimize the impact on the environment. The aim is that the CIGS technology should be brought to a state where performance and manufacturability make it ready for large-scale commercialization.

DEVELOPMENT

The national programme on PV systems and applications is focused on system integration. It has in somewhat switched from an energy perspective towards a PV in buildings perspective. Architects represent new partners, but it still primarily involves energy and building industries.

The vision is that the market for PV will expand from stand-alone applications to power production through grid-connected building integrated and other decentralised PV systems. This expansion however, depends on PV systems and applications knowledge among the future industrial partners in the PV area. To fulfil the vision and contribute to the reduction of the critical PV system costs, the programme goal is to enhance knowledge about PV as an energy source as well as a building component, identify possible applications of PV and raise the commercial awareness concerning PV systems.
The programme includes coverage of the rapid international development concerning PV systems in general and for grid-connected building integrated PV systems in particular. The programme does provide a basis for international exchange, such as the participation in IEA PVPS.

The programme performs evaluations of procurement, installation and start-ups for Swedish PV installations. It is also defines and implements a monitoring process for existing and future grid connected Swedish PV-installations.

Efforts concerning PV niche applications are focused on cathodic corrosion protection of power pylons and remote controlled switchgear in electricity distribution systems. Previous results indicate that both applications could be cost-effective. The potential market is large and not limited to Sweden and further steps to realise applicable and improved system configurations are being undertaken.

A promising concept for increasing the amount of irradiation and thus lowering the cost of PV systems is the use of reflectors. The development of reflector and hybrid-concepts for PV-systems are important efforts within the programme. In addition, interesting synergies with Ångström Solar Center CIGS-modules have been identified and implemented through tests with prototype modules.

The interest from the Swedish building industry is focused on building integrated PV systems. Recent program activities include information, education and development of tools for physical planning and design with PV in the built environment.

DEMONSTRATION

A number of niche applications have been demonstrated. Demonstration of grid-connected PV systems is at present limited to a few smaller systems.

The awareness of PV in buildings has started to rise through demonstrations such as Älmhult (IKEA), Gothenburg, Kristianstad and The Nordic Ark. In the near future, we are to see further developed demonstrations of PV in buildings. One example is the results of an environmental competition concerning Hammarby Sjöstad, Stockholm's largest residential building project. The winning contributions by NCC AB and JM Byggnads AB (see figures) as well as Familjebostäder and SBC will be realized and comprise PV-solutions.

As PV is a promising energy source for the future, schools are a good base for implementing the technology. EU/Alterner has approved a Nordic PV School Programme. It will hopefully lead to several grid-connected PV systems on Swedish schools.

Sickla kaj by NCC AB (Architect: White Arkitekter). Winning contribution to the environmental competition announced by the City of Stockholm. NCC AB will install a total of 420 square meters of PV in their Hammarby Sjöstad projects. (Photo White Arkitekter, 2001).

IMPLEMENTATION

In Sweden, there are no general subsidies for PV, contrary to other renewable energy sources like solar thermal, wind, hydropower and biomass. The Swedish policies, which indirectly could promote the use of PV power systems, are taxes and fees related to energy production and environmental protection. The current levels of these taxes and fees, at current PV system prices, are however too low to have an impact on the PV market in Sweden. Instead, in the current pre-commercial state of PV, new installations of significant size would most likely be considered as a demonstration system and receive support from governmental funds. With this funding, the public support can be up to 50% of the innovative part of a demonstration project.

Since PV is a long term sustainable renewable energy technology the general view on PV in Sweden is positive and the interest from the industry has increased. The solid and steady progress, which has occurred during the recent years, has been noted and hopefully it will develop over the coming years. However, PV will probably not be utilised for large-scale electricity power generation within the next 5-10 years.

INDUSTRY STATUS

The PV industry in Sweden consists primarily of four companies, Gällivare Photovoltaic AB, ArcticSolar AB, Sun Peak AB and Naps Sweden AB.

Gällivare Photovoltaic AB, ArcticSolar AB and Sun Peak AB are producers of photovoltaic modules. They are all situated north of the Arctic Circle in Lappland. Together they offer a wide range of products of standard modules. The companies can also manufacture customer-designed modules and laminates for building integration and other special applications.
Naps Sweden AB is designing, marketing and selling products and systems based on PV modules. System controllers and the majority of solar modules are of their own design. Naps Systems has experience in consumer applications, industrial applications, rural electrification and on-grid distributed systems. Naps Systems Oy, a company in the Fortum Group, owns the company.

MARKET DEVELOPMENT

The total installed capacity during 2000 was 221 kWp, which is approximately the same as in 1999. The main volume of the Swedish PV market is in the domestic-off-grid sector. More than 90 % of the installations during 2000 were in this category. By the end of 2000, the total cumulative installed capacity in Sweden was about 2,8 MWp.

No grid-connected system was installed during 2000. Several projects are, however, planed for the coming years, i.e. approximately 80 kWp grid-connected installations are planned in Hammarby Sjöstad.

The main part of the system components is imported and the dominant fraction, around 95%, of the Swedish module production is exported. The module production was approximately 2 MWp /year (50 % monocrystalline and 50 % multicrystalline) in 2000, but is expected to increase to 4 MWp /year in 2001 and 12 MWp /year in 2002 when ArcticSolar AB and Sun Peak AB have expanded their capacity.

FUTURE OUTLOOK

The high quality research and development that is carried out at Ångström Solar Center will continue. The ÅSC programme is highly relevant for the Swedish Energy Agency since it deals with important issues for a future sustainable energy system and potential commercial ventures beneficial to Sweden.

In the near future we are probably going to see new initiatives bringing PV closer to the commercial on-grid electricity market. These initiatives could be realized in co-operation between traditional and partly new but essential actors, such as architects and building companies, which can make a contribution to market development driven by other factors than energy prices.

This, together with enhanced user oriented knowledge, through the national co-financed programme on PV systems and applications, will form the basis for future initiatives in Sweden.

SWITZERLAND

PV TECHNOLOGY STATUS AND PROSPECTS
BY STEFAN NOWAK, NET NOWAK ENERGY & TECHNOLOGY LTD.,
ON BEHALF OF THE SWISS FEDERAL OFFICE OF ENERGY (SFOE)

GENERAL FRAMEWORK

For the policy framework, the year 2001 was characterised by the launch of the new Swiss energy programme, SwissEnergy (www.swiss-energy.ch). SwissEnergy is a Swiss federal government programme for the promotion of renewable energy and more efficient use of energy. It involves the collaboration of the cantons and of a great many local authorities as well as the private sector, and various environmentalist and consumer groups. SwissEnergy is the follow-up to the Energy 2000 Action Programme and like it, will have a duration of 10 years.

The objectives that have been set for the new SwissEnergy programme are derived from the Swiss federal constitution, the federal energy law and the CO_2 law, and also reflect Switzerland's commitments under the international convention on climate warming. Specifically, these objectives are as follows:

- The consumption of fossil fuels in Switzerland and the corresponding CO_2 emissions must be reduced by 10 percent between 2000 and 2010.
- The growth of electricity demand must not exceed 5 percent.
- Hydropower's share of final electricity consumption must not be reduced despite deregulation of the Swiss electricity market.
- The contribution made by other forms of renewable energy must increase to 0.5 Terawatthours (TWh) or 1 per cent of total electricity production, and in the case of heating energy to 3 TWh or 3 per cent of the total.

Other important SwissEnergy objectives that are less easy to measure include the development of a greater awareness of the energy dimension among the general public as a prerequisite for the optimum implementation of voluntary measures; even closer cooperation among all partners; a spirit of innovation in all fields and an overall strengthening of the Swiss economy in the end.

Fig. 1 - Photovoltaic metal roof system using amorphous thin film solar cells. (photo NET)

Fig. 2 - The worlds largest solar electricity boat, Mobicat, for 150 passengers. (photo NET)

NATIONAL PROGRAMME

The national photovoltaic programme focuses on R&D,D in a market oriented approach, with the implication of a broad set of stakeholders, from basic research, over applied research, product development, pilot and demonstration projects all the way to market stimulation. To increase the quality of new systems, a number of software tools for improved project design and recommendations for project implementation are available. Further accompanying measures which help to support and promote market deployment include the customer-oriented promotion in the campaign "solar electricity from the utility." Finally, the programme emphasizes information and communication in order to raise the awareness for opportunities involving photovoltaics. Direct promotion of the market through incentive schemes has become the responsibility of the cantons on a voluntary basis. This has lead to regional differences whereby the governments of the cantons define their priorities between promotion of energy efficiency and/or renewable energies.
On the technical level, thin film solar cells and building integration remain the foremost topics of priority. The subject of technology co-operation with developing countries has gained increased interest and new concrete activities are in progress.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The Swiss Photovoltaic RTD Programme is based on a 4 year RTD concept, presently covering the period from 2000 – 2003. Overall, 80 projects, supported by various national and regional government agencies, the research community and the private sector are conducted in the different areas of the photovoltaic energy system. Market orientation, cost reduction, industrial viability and transfer as well as increased efficiency and reliability are the main objectives of the technical R&D.

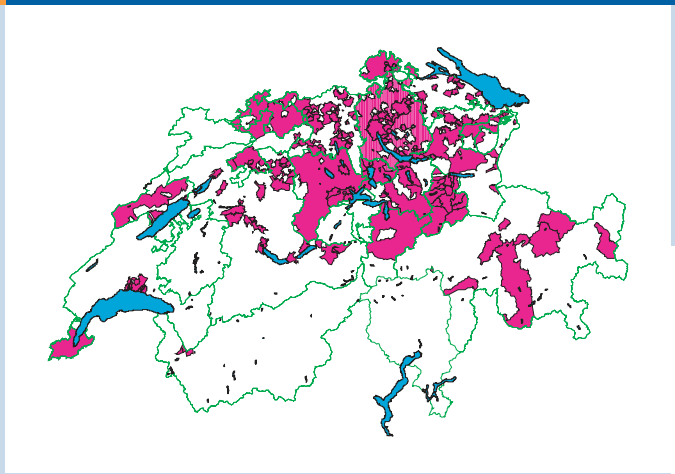


Fig. 3 - Availability of solar electricity in the service territories of the Swiss utilities

For solar cells, the main focus remains on thin film solar cells with projects in a wide variety of materials (amorphous and microcrystalline silicon, silicon-germanium, compound semiconductors, dye-sensitised cells). Depending on the advancement of this R&D work, transfer to industry is more or less developed. A number of new ventures with industry have begun throughout the year. Further basic R&D is carried out in new materials, e.g. in zeolyte crystals. A strong emphasis is placed on the application of building integration, both for new solutions involving thin film solar cells as well as for new mounting systems and structures for sloped roofs and facades.
Two new roof mounting systems involving advanced frames (Solrif® and AluTec / AluVer®) have been particularly successful in the market, corresponding to about 5 MWp of installed power, and have resulted in considerable export shares. New building integrated projects have been realised with thin film modules (Figure 1), including CIS cells. Stand-alone systems have found new applications in solar boats, including the world's largest solar driven catamaran (Figure 2) for 150 passengers.
With the ongoing market development, quality assurance of products and systems, as well as standardisation are becoming topics of high priority. Three centres of competence have been established which evaluate products such as PV modules, inverters and components for building integration. Long term experience with the operation of photovoltaic power systems is carefully tracked for a number of grid-connected systems, ranging between 10 and 20 years of operation. International co-operation continues to form a strong pillar of the R&D activities with about 20 projects running in the RTD-programmes of the European Union. International projects are also carried out as part of programmes such as the European Union Altener Programme or the European Space Agency. The co-operation within the IEA PVPS programme has remained a further strategic activity for which target-group specific dissemination is crucial.

IMPLEMENTATION

The majority of the market implementation of PV systems continues to be driven by the campaign for "solar electricity from the utility." By the end of 2001, more than 130 utilities (1996: 7) provided solar electricity to their customers. Different financial models are being implemented according to the preferences of the utilities.
Meanwhile, more than 50% of the Swiss population have access to solar electricity and more than 30 000 customers annually subscribe to about 4 GWh of this new energy service (Figure 3). Through the past 5 years, this concept has enabled about 5 MWp of PV systems installed with a high awareness effect among the public. The campaign has proved to be a successful approach, involving different stakeholders, provided a strong and consistent marketing is undertaken. Benefits were identified also by the utilities in introducing new customer relationships.
With the introduction of the labels "naturemade basic®" and "naturemade star®" for green power products (www.naturemade.ch), promotion of green power includes portfolio approaches of different technologies. For the "nature made star®" label, 2.5% of the total energy delivered in a service area has to be from new renewable energies (photovoltaics, wind, biomass). Using these labels, green electricity is now also promoted as part of the SwissEnergy programme.

INDUSTRY STATUS

Swiss industrial PV products cover mainly system components such as inverters, both for grid-connected and stand-alone applications, components for electrical connection, mounting systems for building integration and custom designed PV modules. On the PV industry supply side, different products count among the world leaders, e.g. for wire-sawing machines and measuring equipment for PV module manufacturers. In the past, assembled PV modules based on crystalline silicon technology were introduced into the market to form aesthetically attractive products for building integration. Whilst the main market driver, the campaign "solar electricity from the utility," has favoured least cost solutions on flat roofs (Figure 4), industrial development shows a trend towards higher integration and innovation, partly with thin film technologies.
More recently, industrial activities have started in the field of process equipment and small scale products based on thin-film technology. This development reflects the existing technological know-how within the research community, combined with an increasing awareness of new market opportunities by the industry.

Fig. 4 - 240 kWp PV system on the Basel fair building. (photo energiebüro)

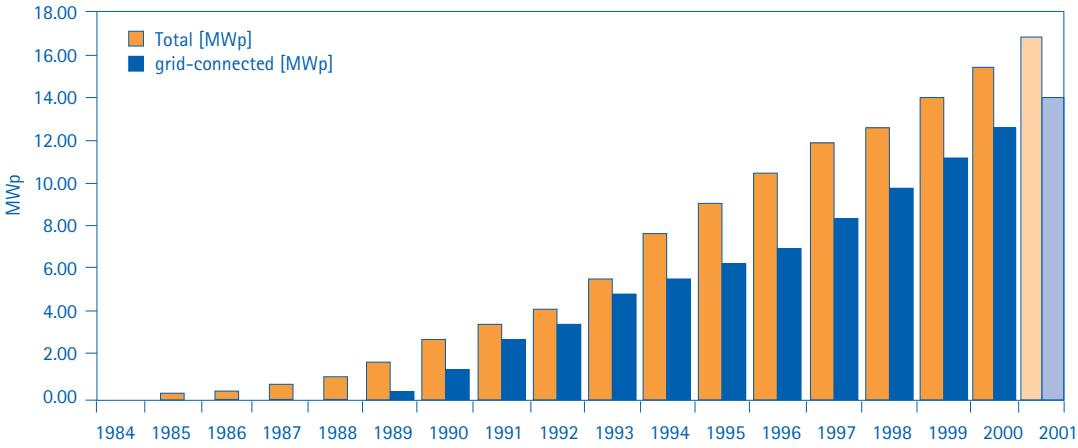


Fig. 5 – Evolution of the installed photovoltaic capacity in Switzerland between 1984 and 2001 (total and grid-connected, estimated values for 2001)

Based on the long term experience and the large number of installed systems, considerable know-how is available amongst engineering companies for the design, construction and operation of a large variety of different applications, ranging from small scale, stand alone systems for non-domestic, professional applications and remote locations, over small domestic grid-connected systems to medium and large size grid-connected systems in various types of advanced building integration.

Besides an increased interest from the manufacturing industry, the finance sector continues to promote financial services directed towards renewable energy. A new agency, BASE, (www.energy-base.org) seeks to facilitate investment in renewable energy and energy efficiency projects. Increased investments have occurred in the renewable energy sector, including photovoltaics, and dedicated funds are operated by important finance organisations. This trend clearly demonstrates the growing perception of the renewable energy sector as a field of increasing business opportunities.

Following the results of the referendum regarding Swiss energy policy in the year 2000 and a stagnating market for grid-connected systems, a certain consolidation of the industry can be observed with a trend to more international involvement of the engaged companies, both in market orientation as well as industry and investment structure.

MARKET DEVELOPMENT

Market development has been mainly driven by the federal campaign "solar electricity from the utility," supported by promotional programmes and actions in some cantons as well as pilot and demonstration projects within the national programme. The annual market volume for grid-connected systems is estimated to be about 2,2 MWp, that is in the range of previous years. The total installed capacity thus rises to about 17 MWp (Figure 5), corresponding to about 2,4 Wp/capita. The PV energy statistics has been established tracking the energy produced by grid-connected PV systems and their statistical distribution since 1992 (Table 1).

FUTURE OUTLOOK

Regarding photovoltaic technology in Switzerland, the broad support for the national PV programme can be expected to continue with an ever-increasing focus on industrial developments, new products for niche markets and ongoing international involvement. For solar cells and modules, the effort to bring Swiss technology to the market place will continue. Efforts in the technology development will concentrate on market oriented approaches and continuous quality assurance.

PV market implementation will continue to be limited to indirect promotion measures within the federal energy programme, the activities of regional authorities and the initiatives by the utilities. The year 2002 will bring another important energy policy decision relating to the new law on the electricity market. If accepted, this law would favour the implementation and use of renewable energy through preferential conditions in the market access.

The strategy to promote international co-operation on all levels will continue, related to activities in the 5th and 6th framework programme of the European Union, the IEA PVPS programme and in-creasingly in technology co-operation projects.

TABLE 1: SWISS PHOTOVOLTAIC ENERGY STATISTICS FROM 1989 – 2000

Year	Number of New Systems	Total Number of Systems	Installed Capacity [MWp DC]	Energy Production [MWh]	Specific Energy-Production [kWh / kWp]
1989	60	60	0,3		
1990	110	170	0,8	400	
1991	210	380	1,8	1 100	
1992	110	490	3,1	1 800	800
1993	110	600	4,0	3 000	810
1994	80	680	4,8	3 500	800
1995	60	740	5,4	4 000	815
1996	80	820	6,2	4 700	825
1997	130	950	7,4	6 000	880
1998	150	1 100	9,2	7 100	860
1999	125	1 225	11,0	7 700	770
2000	100	1 325	12,7	9 700	810

(grid-connected systems)

UNITED KINGDOM

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DEPARTMENT OF TRADE AND INDUSTRY

GENERAL FRAMEWORK

In the UK, the Department of Trade and Industry (DTI) is the lead Department dealing with energy issues. Other Departments with significant interests are the Department of the Environment, Food and Rural Affairs (DEFRA), the Department of Transport, Local Government and the Regions (DTLR), the Cabinet Office and the Treasury.

The increasing importance of renewable energy sources to the UK in terms of meeting emission reduction targets, contributing to diversity and security of supply and developing internationally competitive industries has been recognised and has led to a number of significant policy initiatives.

The Government has imposed an Obligation on electricity suppliers (the Renewables Obligation) which requires them to deliver a specified proportion of their supplies from electricity generated from specified sources of renewable energy, or to buy Renewables Obligation Certificates or to make a buyout payment. This will enable the UK to make progress towards its target of generating 10% of its electricity from renewable energy sources covered by the Obligation by 2010. This forms the main element of the Government's strategy for renewables deployment but it has been supplemented by a number of other initiatives described below.

In November 2001, the Performance and Innovation Unit (part of the Cabinet Office) published its report detailing how an additional GBP 100m of funding for renewables - previously announced by the Prime Minister - should be spent. The Performance and Innovation Unit has also been conducting a review of Energy Policy which is expected to be published in early 2002. The review is addressing issues such as the scope for increased targets for renewables in the post 2010 period. A draft strategy and consultation paper – "Powering Future Vehicles"- was published in December 2001. It sets out the Government's proposed approach for moving towards low-carbon vehicles (hybrids and fuel cell powered).

NATIONAL PROGRAMME

For photovoltaics, the UK's National Programme consists of the following elements:

- research and development, under the DTI Sustainable Energy Programme and the Engineering and Physical Sciences Research Council (EPSRC) programme
- field tests and demonstrations, under DTI programmes
- participation in international programmes (EC and IEA)

The overall goal is to develop the capabilities of industry and to encourage sustainable growth in the market by removing barriers to the deployment of PV.
A Photovoltaic Government – Industry Group, set up at the request of the then Minister for Energy, Helen Liddell, made a series of recommendations to Government in its final report, dated 26 March 2001. These included the need for a market stimulation programme for

Fig. 1 - Greenfields- A solar collector, natural ventilation flue and light pipe are also saving fossil fuels on this roof.

domestic and non-domestic PV systems, simplified connection arrangements, consideration of net metering, and setting up a national training and accreditation scheme for installers and service personnel. These and the other recommendations of the group are being taken forward by the Department of Trade and Industry and others.

RESEARCH, DEVELOPMENT AND DEMONSTRATION

The existing DTI Sustainable Energy R&D Programme has been strengthened through the preparation of "Technology Route Maps" for each technology in consultation with industry. This has resulted in an improvement in the quality of proposals received as response to the periodic competitive calls for proposals. Funding of the PV element of the programme is running at about GBP 2 million per annum, but will increase significantly over the next 3 years.

The current priorities for work supported under the R&D Programme are as follows:

- the identification, development and evaluation of novel materials and/or cell structures which offer significant improvements to current PV performance and costs;
- innovative approaches to existing cell or module technologies with the goal of improving performance and/or reducing costs
- identification, development and evaluation of new production methods and processes which offer significant potential for cost reduction
- innovative approaches to balance of systems technologies such as power conditioning equipment, metering, wiring and installation systems with a view to significant improvements to the cost or performance.

Fig. 2 - Retrofit PV at Hunters Moon.

The DTI is working with a number of industrial partners to pursue these objectives. Work includes development of amorphous silicon, high efficiency thin film silicon and organic cells.
The Field Trial of Domestic PV Systems referred to in the previous IEA PVPS Annual Report is underway. The budget of GBP 1.4 million is supporting 9 projects with 166 dwellings totalling 220kWp. A second phase of the trial was announced in October 2001 with a budget of GBP 4 million. This will allow for PV to be installed on 379 dwellings on 23 sites with a total capacity of over 600kWp. A similar field trial for larger systems (non-domestic) for public sector buildings was launched in November with a budget of GBP 3 million and applications were being assessed at the time of writing. Both the Domestic and Non-Domestic Field Trials are now closed to new applications.

IMPLEMENTATION

It is intended to launch the Major PV Demonstration Programme in the first quarter of 2002 (subject to EC State Aid approval). This will be the first phase of a potential 10 year programme which would rival the deployment programmes of Germany and Japan. Funding of GBP
20 million has been allocated for the first phase (3 years). The programme will provide capital grants for the installation of domestic and non-domestic PV systems in the public and private sectors.

The process for obtaining network connection for small PV systems has been simplified and improved. Draft network connection guidelines (G77) have been circulated for some time but a further round of development has recently been completed involving the PV industry and utilities. This has resulted in a revised version of the recommendations which are expected to be published formally shortly.

INDUSTRY STATUS

The UK's only indigenous producer of photovoltaic panels (Intersolar) has trebled its capacity to 3MW using private capital. Intersolar is also embarking on a major R&D programme covering both manufacturing process and product development with assistance from the Department of Trade and Industry. Crystalox has expanded its capacity to maintain its position as one of the world's major suppliers of silicon ingots.

MARKET DEVELOPMENT

By the 31 December 2000, the totalled installed PV capacity in the UK was 1 929 kW, of which 1 506 kW (78%) was on-grid distributed. This represents a 70% increase over the previous year. Anecdotal evidence suggests that an additional 1MW was installed during 2001, but this is subject to confirmation. Solar Century, a solar solutions company has been very successful in building new business although BP Solar remain responsible for the lion's share of installations, largely on BP's own buildings and service stations.

FUTURE OUTLOOK

The Major PV Demonstration Programme will provide a significant boost to PV in the UK. Installer accreditation and training, and grid connection issues will become more important as the level of installed capacity begins to ramp up significantly. There has been a significant increase in the level of interest in the UK PV market from manufacturers across the world since the programme was announced.

Significant cost reductions together with steady improvements in the quality, reliability and service of systems will be vital to underpin the sustained growth of the sector.

Fig. 3 - PV within double glazing on the zero emissions housing project, BedZed.

THE UNITED STATES OF AMERICA

PV TECHNOLOGY STATUS AND PROSPECTS

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GENERAL FRAMEWORK OF PHOTOVOLTAIC (PV) ACTIVITIES IN THE U.S.A.

The U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy directed the U.S. PV Program through its Office of Solar Energy Technologies in the U.S. through September 2001. Beginning in October, the U.S. DOE reorganized its renewable energy work into a new National Solar Program. The U.S. DOE was the leading funding source for PV research and development in 2001 and it offered the resources of the national laboratories to assist in the PV industry's applied research and development (R&D) activities. The Office of Energy Efficiency and Renewable Energy, led the national laboratories to develop comprehensive operating plans based on strategic, multiyear plans that respond to the broad policies for energy R&D determined by the executive and legislative branches of the federal government. The National Center for Photovoltaics (NCPV) worked with the PV industry through various cost-shared programs to develop and improve component designs, device manufacturability and systems. Education, technical transfer, technical assistance and competitive contracts were used extensively to accomplish the work in 2001. PV-related activities funded by the DOE were balanced between PV cell and module development, manufacturing, balance-of-system and system technologies. The U.S. Department of Energy web site (http://www.eren.doe.gov/pv/) provides up to date information on and links to all aspects of the PV activities in the U.S.

The "Industry Roadmap," refined in December 2000 unifies the vision and long-term (2000-2020) strategies and goals for the PV industry. The vision provides the electrical/energy consumer competitive and environmentally friendly energy products and services from a thriving U.S.-based solar electric power industry. The "DOE PV Program 5-Year Plan (2000-2004)" that was written in concert with the industry roadmap plan helps to guide the national PV activities. In addition, the U.S. DOE Million Solar Roofs Initiative promoted the reduction in greenhouse gas and other emissions and State and local partnerships, financial tools, consumer awareness, and support with codes, standards, and certification programs.

The National Center for Photovoltaics (NCPV), an alliance of organizations, serves as the focal point for the nation's capabilities in PV technologies and has proven to be an effective structure for planning and implementing the national PV activities. The R&D goals and strategies are formulated each year by a governing board in concert with the "Industry Roadmap" and through an all-encompassing annual operating plan.

PV technologies for both thin-film devices and crystalline devices continued partnership programs in 2001. The Thin-Film Partnership Program and the Crystalline Silicon Research Cooperative collaborated with manufacturers on technology issues that were common to all manufacturing processes and non-proprietary in nature to pool the nation's resources in order to maximize technology advancement.

PHOTOVOLTAICS (PV) ACTIVITIES IN THE U.S.

The federal PV activities are directed through the U.S. Department of Energy (DOE) with headquarters in Washington, DC, and by research centers at the National Renewable Energy Laboratory (NREL) and at Sandia National Laboratories (Sandia). The goals of the U.S. PV activities are to accelerate the development of PV as a national and global energy option and to ensure technology and global market leadership for the nation. The dissemination of information pertaining to PV technologies was handled through printed reports, web sites, and conferences. The National Solar Program shared the costs of numerous pilot projects and applied research. The authorized funding was categorized into three major areas for FY2001 for PV.

Fundamental Research	24% of the budget
Technology Development	26% of the budget
Advanced Materials and Devices	50% of the budget

The total FY2001 federal budget for the Photovoltiac component of the National Solar Program totaled USD 74.26 million.
Additional support for PV-related projects came from state and local governments, the PV industry, and utilities.

The NCPV relies on the core expertise of NREL and Sandia to create, develop, and deploy PV and related technologies. Other national PV resources that the NCPV draws on are Brookhaven National Laboratory, two Regional Experiment Stations (the Florida Solar Energy Center and the Southwest Technology Development Institute), and U.S. DOE Centers of Excellence in PV at the Georgia Institute of Technology and the University of Delaware (Institute of Energy Conversion). In addition, more than 100 university, industry and utility research partnerships across the country are linked together to function in a unified way. The NCPV awards most of its federal funds through competitive procurements to industry, universities, and other research centers.

RESEARCH AND DEVELOPMENT

The national PV effort included fundamental, advanced materials, device, and manufacturing R&D. Critical PV program contributions were provided through national laboratory support to the industry through basic research, device characterization, and environment, safety and health activities. A web-based virtual laboratory allowed collaborators from universities and industry to access real-time data on test results related to their projects.

Thin-film devices and materials development continued through the NCPV and the Thin-film Partnership Program. Thin-film devices include amorphous silicon (a-Si), copper indium diselenide (CIS), copper indium gallium diselenide (CIGS), cadmium telluride (CdTe), thin-film silicon and others. The Thin-film Partnership Program helped to commercialize these promising technologies and began awarding contracts for the next round of research to 19 universities and

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a Lockheed-Martin subsidiary, for the U.S. Department of Energy, contract #DE-AC04-94AL85000

Fig.1 - Barns at Franklin Park 80 kW Millennia PV array and part of an innovative hybrid power system. Photo Courtesy of BP Solar.

14 companies. A total of USD 40 million will be awarded while awardees will cost share USD 13 million. Among this year's achievements were efficiency records, gains in cell and module processing techniques, and new commercial production facilities. Responding to sustained research efforts, the efficiency of thin-film devices is steadily rising. In 2001, large area amorphous silicon (a-Si) modules showed stable efficiencies that were up to 7.9%; cadmium telluride (CdTe) modules that were rated 11.0% efficient; and CIS-based modules that were rated up to 12.1% efficient.

Research on Amorphous Silicon (a-Si)

Research has moved efficiencies of a-Si devices toward the national goal of 13% efficiency and methods for increasing the deposition rate of a-Si were successful. United Solar Systems increased a-Si production to 3.8 MW in 2001. BP Solar continues to operate its 10-MW/year plant with enhanced throughput that produces tandem-junction, a-Si alloy modules in the 43 to 50-W range with glass-to-glass encapsulation.

Research on Cadmium Telluride (CdTe)

PV devices using CdTe can be manufactured using potentially low-cost techniques such as spraying, electrodeposition, and high-rate evaporation. Achieving high laboratory efficiencies using these low-cost techniques is an important objective of the National Solar Program. To date, more than ten techniques have been used to grow CdTe layers resulting in cells operating at efficiencies greater than 15%. Three of these methods are currently used in industry. BP Solar produced a CdTe module with an aperture area efficiency of 11% and power output of 92.5 W. First Solar, LLC has advanced its ultrahigh-rate vapor transport deposition through collaboration with the NCPV.

Research on Copper Indium Diselenide (CIS) and Copper-Indium-Gallium-Selenide (CIGS)

Two major goals for CIS research are to transfer years of government-sponsored research to industry for pilot-scale manufacturing and to produce commercial modules. NREL scientists achieved replicable CIGS cells with efficiencies of 21.1% under 14-sun concentration. Industry explored new deposition systems for large-area CIS devices. The Institute of Energy Conversion produced solar cells with 16.9% efficiency using a new Cu(InAl)Se2 absorber layer.

Commercial products using CIS alloys were sold by Siemens Solar Industries (SSI) and by Global Solar in 2001. SSI produced 5- to 40-W PV modules made of CIS alloys that were up to 10% efficient. Global Solar produced new flexible modules (4.9% efficient) for a variety of field applications. SSI developed the new products using copper-indium-gallium-sulfur-selenide (CIGSS) under contract to the Thin-film PV Partnership Program.

Research on Crystalline Silicon (c-Si) PV

Because more than 90% of PV power systems sold today are made of crystalline silicon (c-Si), improvements to this technology have the potential for quick advancement to the marketplace. Fundamental research for scientific advances through the Crystalline Silicon Research Cooperative and other programs in crystalline silicon technologies continued in 2001. The program sponsored the 11th Workshop on Crystalline Silicon Materials and Processes to effectively communicate research results. Researchers at Sandia developed a plasma texturization process for multi-crystalline cells known as reactive ion etching. The process boosts the performance of cells by 10%.

Research and Development of the Balance-of-System

Research within the industry and the national laboratories has explored improved solid-state switching methodologies for inverters, new control firmware and software, new balance-of-system hardware designs, and entire PV systems that are cost effective. Inverter improvements include higher efficiency, reduced operating losses, lowered cost, improved quality control, smaller size and conformance with anti-islanding and code requirements. Many of the new grid tied installations also use battery storage. Sandia maintains a program to evaluate and improve batteries and charge controllers for PV applications. Issues pertaining to environment, safety and health remained an essential aspect of working with the balance-of-system industry and were included in all work sponsored by the National Solar Program.

Research on High Performance and Concentrating PV

The National Solar Program contains a 10-year program goal to double the efficiency of multi-junction thin-film modules. There is also a goal to demonstrate a high-efficiency III-V cell in a pre-commercial concentrator module. To help achieve this objective, the High Performance PV Initiative was begun in 2001. The NCPV and Spectrolab are collaborating toward a goal of a 40% cell under concentrated sunlight. Spectrolab demonstrated a 34%-efficient cell under 600-sun concentration. Work continues on several fronts to develop materials that will perform well at very high concentrations of sunlight.

Fig. 3 - Los Angeles Convention Center Canopy completed September 2001 produces 250 kW ac power. Photo by Monica Estrata and courtesy of Los Angeles Department of Water and Power.

MANUFACTURING AND IMPLEMENTATION

Industry Roadmap

Success of the PV component of the National Solar Program depends on the direction, resources, best scientific and technological approaches, use of the best technologies and continued efforts of the best and brightest among industry, federal laboratory and university partners. The NCPV worked in concert with the industry to revise the "Industry Roadmap" to support work that focused on the roadmap's vision and strategies to provide competitive PV products and services.

Photovoltaic Manufacturing

In 2001, the U.S. PV industry marketed about USD 1 billion of the world's USD 2.5 to 3.0 billion of product. To maintain technology leadership and market share, improvements in product must move from U.S. laboratories to the world marketplace. Against this backdrop of a growing market, the PV Manufacturing R&D Project initiated a new solicitation, "Photovoltaic Manufacturing R&D—In-line Diagnostics and Intelligent Processing in Manufacturing Scale-Up." This solicitation encourages teams to share the cost of high-risk research to develop intelligent processing for larger scale manufacturing that will be the foundation for achieving the goals set out in the U.S. Photovoltaic Industry Roadmap. Since Congressional funding for manufacturing research and development began in 1991, great progress has been made in reducing the cost of PV systems and improving the performance and reliability of commercial products. Work under previous subcontracts awarded under PV Manufacturing Technology (PVMaT) solicitations was completed in 2001, just as the new set of contracts was awarded. Final reporting will continue into FY 2002. The 14 subcontracts awarded in FY 1998 will total about USD 60 million over a 3-year period with 48% subcontractor cost-sharing.

Fig. 2 - Long Beach Bike Station Includes 2 kW PV. Photo by Monica Grau and courtesy of Los Angeles Department of Water and Power.

Systems Research and Development

A systems engineering program that included a balance-of-system program was accelerated this year with Sandia leading efforts to fund evolutionary changes to power processing hardware resulting in improved reliability and performance. The reliability of required switchgear, ground-fault detection and interruption equipment, and component safety certification programs was also funded. Sandia continued working with industry in 2001 to improve "Total Quality Management" programs in the manufacturing and assembly areas. Sandia also assisted industry in "Highly Accelerated Life Tests (HALT™)" and "Highly Accelerated Stress Screens (HASS™)" to improve quality and reliability of hardware. The test facilities at Sandia and NREL continue to contribute significantly to all of the reliability-improving programs.

NREL and Sandia conduct module performance and durability studies for manufacturers based on data from several test sites. For new modules or for ones that have operated in the field for years, researchers collect data on electrical performance, extent of delamination, integrity of solder joints, and properties of encapsulants. Tests include outdoor electrical performance, dark current/voltage (I-V), infrared (IR) imaging, ultraviolet (UV) inspection, solder-joint metallurgy, and ultrasonic characterization, as well as destructive testing for specific failure modes.

An inverter test facility at Sandia provides for hardware characterization, surge testing and accelerated life testing. A new 30-kW hybrid test bed for inverters is designed for grid-connected or standalone PV systems. In FY 2001, Sandia designed and began operation of a Distributed Energy Test Laboratory (DETL) that includes a 75-kVA microturbine; a 90-kVA diesel; and load banks that are resistive, inductive, and capacitive in nature. The product of an agreement with the Salt River Project and Sandia, this DETL can be used to study the effects of any distributed generation system (including PV and PV hybrid systems) on electrical utility operation.

NREL maintains the Outdoor Test Facility (OTF) to test performance and reliability of solar cells, modules, and small (1–5 kW) systems. The OTF also calibrates primary reference cells for use in house, by other national laboratories, by industry, and by universities. Researchers at the OTF measure performance in actual outdoor tests and using solar simulators indoors. Indoors at the OTF, modules are

tested for failure and performance in conditions of high voltage, high heat, high humidity, flexing, static loading, and simulated hail strikes. Outdoors, test beds at the OTF measure long-term performance and stability. Two test beds perform stress tests of modules under accelerated conditions of high voltage and high sunlight concentration.

Sandia sponsored a Photovoltaic System Symposium in Albuquerque, which was attended by more than 200 people from industry, government, utilities, and educational institutions. Participants shared diverse experiences in implementing PV projects and discussed a systems approach to meeting the 20-year production goals of the PV industry roadmap. Such an approach includes increasing reliability, improving performance, reducing life-cycle costs, removing barriers, and expanding markets.

Although manufacturers are now offering 10- to 15-year warranties on PV modules, PV systems that operate reliably for 25 years are the goal of the PV system activities. To reach that goal, the program is supporting research and analysis using field data and models to identify areas for further technical development. Sandia drafted a "PV System Reliability Plan" in consultation with industry. The plan recommends continuation of several activities such as: developing a reliability database to improve understanding of the performance of real systems; examining PV systems and components after extended operation in the field to identify sources of performance degradation or failures that could be prevented by changes in manufacturing; modeling system performance to identify fault-tolerant designs, sensitivity to component failure, and cost-effective component replacement strategies; and working with industry and users to resolve technical or institutional barriers to system reliability.

MARKET DEVELOPMENT

Created in 1992, TEAM-UP (Technology Experience to Accelerate Markets for Utility Photovoltaics) was a partnership between the U.S. DOE and the utility industry to help develop commercial markets for a wide range of solar electric technologies. TEAM-UP was successfully completed in 2001. The TEAM-UP program issued funding awards to 36 teams to install more than 7.4 MW of solar electric systems in more than 1,100 installations in 34 states across the United States. Private funds support the ventures at a cost-share ratio of four dollars of private funds to every dollar of DOE funds. In FY 2001, the project continued technical and financial monitoring and documentation of the 36 TEAM-UP ventures.

The National Solar Program provided continuing support for state-supported PV applications using assistance through the Interstate Renewable Energy Council (IREC). Much of this work provided PV applications and education for parks and public spaces through the "Photovoltaics for Utilities (PV4U)" program. This approach to removing barriers to PV for utilities is a network of State working groups that promote PV. Working with the States for "A National Certification Program for Practitioners" and later PV hardware became a focal point for the IREC program in 2001 featuring workshops and special sessions at conferences.

Fig. 4 - Fountain Valley City Center uses two PowerGuard (110kW) PV systems. Photo Courtesy of PowerLight.

Making way for new strategies, the phased research and product development program known as PV: BONUS was nearing completion in 2001. Initiated in 1993, this was the first DOE effort to foster the development of products for the building industry that included photoelectric conversion features. The project conducted competitive solicitations that resulted in 38 partnerships and 10 new products for the residential and commercial buildings market. Partnerships that brought products to market included members with knowledge of the building industry, as well as photovoltaics, who worked together to design, develop, and manufacture the products.

There is a huge potential market for installing solar electric systems as an alternative to upgrading aging power lines to existing electric water pumps in the U.S. If 5% of all applications in the rural electric cooperative system were replaced with PV, the market would equal 50 MW. Barriers to this large potential market for PV systems are being addressed when NCPV personnel provide analysis and technical assistance to organizations such as the U.S. Department of Agriculture's (USDA) Rural Utility Service, the U.S. Department of Defense, the U.S. Agency for International Development, the Florida Solar Buildings Program, the U.S. Bureau of Reclamation, Mexico's Agricultural Secretariat, the Salt River Project, and the Navajo Tribal Utility Authority (NTUA).

No major national demonstration programs were active during 2001. Several new programs were sponsored by various sectors of state governments and utilities, most notably California. Deregulation of the electric utilities and localized energy shortages have spurred several state programs that require installation of PV energy systems along with new R&D efforts aimed at fielded PV systems.

ELECTRICAL AND PERSONNEL SAFETY THROUGH CODES AND STANDARDS

As more installations of PV systems occur, the electrical and personnel safety of the systems are undergoing more thorough examinations by designers, installers, inspectors and users. Vital utility and industry issues, such as codes and standards, are continuing activities in the National Solar Program. The program supported work to provide a consensus of industry input into the **National Electrical Code® (NEC®)**, listing and certification standards, and numerous

Fig. 5 - Complete listed PV systems are increasingly being included in new housing construction. Photo courtesy of AstroPower

standards activities in both the domestic and the international arena. An "Industry Forum" proposed 34 changes in Article 690 of the NEC for the upcoming 2002 Code and most of those proposed changes are now included in the 2002 Code, published in 2001.
The IEEE929-2000 standard spearheaded by Sandia was published in 2000 and now serves to help remove barriers to interconnection of PV systems to the utility grid. The NCPV headed up the IEEE PV standards activities and also actively participated in the International Electrotechnical Commission activities for PV-related international standards. Underwriters Laboratories amended the UL1741 "Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems" and is now considering expansion of the standard to include inverters for all distributed generation.

PowerMark Corporation continued as a non-profit certification body. PowerMark previously recognized the Arizona State University PV Testing Laboratory (PTL) and approved them for performing module certification tests based on the accreditation certificate they received from the American Association of Laboratory Accreditation. Module models have been qualified to IEEE1262/IEC61215 or IEEE1262/IEC61646 standards since the work began in 1996. The PTL continues to test module types to the UL1703 PV module standard to determine their suitability for listing and has a reciprocity arrangement with European testing organizations.

MARKET DEVELOPMENT INCENTIVES

International work included the Mexico Renewable Energy Program that was sponsored by the U.S. Agency for International Development (USAID) and supported by the U.S. Department of Energy to institutionalize the use of renewable energy technologies. This program had been honored as one of the most successful renewable energy programs for USAID and now serves as a model for increasing the use of renewables in other parts of the world. These projects were implemented in partnership with local Mexican organizations in each geographical or political area to purchase, finance, install and maintain the sustainable systems. This program is resulting in wide-scale system replication, through increased awareness of the benefits of renewable energy technologies, and improved private sector capacities to serve the market. In 2001, Sandia distributed a new CD guide in Spanish for PV water pumping systems.
The NCPV support, such as training and technical assistance in Bolivia, Brazil, China, Ghana, Guatemala, Honduras, India, Indonesia, Kenya, Mexico, Morocco, Nigeria, Pakistan, the Philippines, Russia, South Africa, and Venezuela has helped U.S. companies make inroads into a fast-growing international market.

FUTURE OUTLOOK

The U.S. Department of Energy, in partnership with its national laboratories will continue with strong PV initiatives through the National Solar Program. The "Industry Roadmap" and the "DOE PV Program 5-year Plan" will guide the work. The market development and expansion will include all of the components, interconnects, and materials needed for the PV industry. PV materials, manufacturing processes, balance-of-system hardware, fire and personnel safety, codes, standards, hardware certification and practitioner certification will remain vital elements in the program.
The U.S. DOE Million Solar Roofs Initiative promotes the use of solar thermal and PV to reduce the energy demands of buildings. It enables businesses and communities to install solar systems on one million rooftops across the U.S. The U.S. DOE leads this initiative by working with partners in the building industry, local governments, state agencies, the solar industry, electric service providers, and non-governmental organizations to remove market barriers and strengthen grassroots demand for solar technologies. The "MSRI Action Plan" serves as a guide for the initiative and includes: assistance to MSR "State and Local Partnerships"` through regional DOE offices, enhancement of financial tools available for solar energy, increased consumer awareness, strengthened ties to other Federal Agencies, encouraged adoption of uniform interconnection standards and codes, support for R&D and testing programs, establishment of certification programs, and encouragement to builders and developers to include solar energy systems.

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TASK 9 – DEPLOYMENT OF PHOTOVOLTAIC TECHNOLOGIES: CO-OPERATION WITH DEVELOPING COUNTRIES

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